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PROCEEDINGS OF THE FIRST FEDERAL CONFERENCE ON THE GREAT LAKES

December 13, 14, 15, 1972

Prepared by the Environmental Protection Agency for
the Interagency Committee on Marine Science and Engineering for
the Federal Council for Science and Technology

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First ICMSE Conference on Great Lakes Science and Engineering
Ann Arbor, Michigan December 13–15, 1972,
A Review by the Program Chairman and Proceedings Editor,
Tudor T. Davies

The conference originated in the spring of 1972 when the Interagency Committee on Marine Science and Engineering (ICMSE) requested the Environmental Protection Agency (EPA) to host a conference of Federal Program Managers to review the relevant research programs and plans for Great Lakes activities. The federal agencies within ICMSE which have programs in the Great Lakes appointed prime delegates to help organize the conference, to define its format, and to coordinate their agencies' input to the conference. Some agencies affiliated with ICMSE have no Great Lakes programs and chose not to be represented. The inclusion of the Department of Agriculture, which is not represented on ICMSE, reflected both that department's desire to be involved and the requirements of the other agencies that its programs and representatives be involved in the conference.

In the six months preceding the conference, held December 13–15, 1972 at Ann Arbor, Michigan, considerable effort was expended by each participating agency, particularly by the staffs of the Great Lakes Basin Commission and the Grosse Ile Laboratory of EPA.

The prime delegates and their alternates met on a number of occasions to define the objectives, scope, and format for the conference. The eventual results of their deliberations, and those of their associates, follow in these proceedings.

Objectives

The conference was concerned with the exposition and discussion of federal programs in marine science and engineering affecting the Great Lakes.

One of the main purposes is to effect coordination of federal activities on the Great Lakes. The conference is an avenue for information exchange and dissemination and a vehicle for discussion and planning, and it can provide a mechanism for securing increased emphasis in specific areas. The approaches to some specific problems on the Great Lakes are not yet well defined, and some way of addressing these problems should be developed. It is recognized that this is not the first or the only level at which attempts to coordinate federal efforts are being made, but the objectives of the conference are essential to a significant federal effort in an important area of the country.

Conference Format

The conference was conceptually divided into four parts. The first three parts were concerned with information exchange and dissemination. The final part of the conference was concerned with the discussion, in simultaneous small group sessions, of federal activity concerning problems arising from specific uses of the Great Lakes.

The conference was introduced by an overview presentation from the Chairman of the Great Lakes Basin Commission, who outlined the social-economic framework of the region. He set the perspective for Great Lakes environmental research in terms of the planning activities of the Great Lakes Basin Commission. Improved environmental information is required for a broad spectrum of inter-related natural processes and human activities. The Great Lakes Basin Commission strives for a balanced approach to growth in the Great Lakes region with environmental conservation.

During the meeting, short presentations were given by federal representatives of various international and federal coordinating and scientific groups. These included presentations by the Council on Environmental Quality, International Joint Commission, Great Lakes Fisheries Commission, and International Association of Great Lakes Research. The Secretary of the Interagency Committee on Marine Science and Technology reviewed the origin of the conference and possible alternative objectives. A further overview and evaluation of the effectiveness of the Great Lakes federal programs was provided by an ad-hoc presentation from the General Accounting Office, which reviewed their on-going evaluation of Great Lakes research.

Each agency began its program review with a statement outlining the history, the present legal and conceptual foundation of the agency's role in the Great Lakes, and the present and future direction of its effort. Individual programs were then described in detail.

At the conclusion of these presentations, the conference separated into five discussion groups. The agency prime delegates assigned their delegates to pertinent discussion groups. After an evening session the deliberations of each group were presented to the reassembled conference and briefly discussed. The discussion groups were given general guidelines; however, each group developed its individual initiative and the recommendations of these groups must be reviewed in the light of the specific statement of objectives that precedes each set of recommendations.

These recommendations were reviewed by individual discussion group members after the conference. The chairmen reported to a final meeting of prime delegates and their advisors in January.

The general conclusions from the ICMSE conference are:

1. There is a real need for information exchange and program coordination between the various agencies.
2. At least the exchange of program information was accomplished at the conference, and this is the first step toward bringing about coordination.
3. The real product of the conference was an informal identification by the individual delegates of the omissions and the overlaps of the agency missions and charges, and also an understanding of the magnitude and

rationale for the specific programs of each agency. There were many gaps and some overlaps in the specific programs of the agencies. On close examination, the apparent program overlaps were not found to be duplications in effort. Many programs were inactive because of inadequate funding and a lack of positions.

4. Relatively informal arrangements for coordination of certain federal efforts already exist at the level of the conference delegates, but there is a need for increased coordination at higher management levels.
5. Now that the first step has been made, the conference should meet at least one further time to gauge the influence of the recommendations on the agency programs and plans.
6. The second conference should then have some specific central theme.
7. At some future date the conference should be expanded to include the university, state, and Canadian efforts on the Great Lakes. This step should be made in cooperation with existing coordination efforts.

Tudor T Davies.

TUDOR T. DAVIES
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Nonliving Resources and Water Supply

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* Chairman
**Prime Discussant

The panel on nonliving resources and water supply, in considering the adequacy of the present federal marine science and engineering program on the Great Lakes, raised the following questions: 1) Is the present federal research program adequate? 2) If not, what additional research is required? 3) In view of the conference presentations, is there significant overlap in the federal program? 4) Should increased federal effort be applied? The panel attempted to define the scope of problems relating to nonliving resources and the water supply, with respect to resource operations, development, and management, the impact of resource operations and development on the environment, and the environmental effect on the nonliving resource and water supply.

The term 'nonliving resources' as used in this report refers to the earth materials utilized by man, which may be divided into two categories: mineral resources, found in the coastal zone and on and under the lake bed, which may be extracted and utilized elsewhere; and the land resource of the shoreline and lake bed, which is subject only to modification. We have divided nonliving resources into three categories: sand and gravel; other mineral resources of importance such as manganese, copper, iron, and petroleum; and shoreline resources and beach modification.

The second discussion topic, water supply, was broadened to include water resources. In this report, the term 'water resources' includes municipal, industrial and rural water supply, as well as lake levels, of importance in beach erosion and shore processes, recreation, transportation, power and fisheries. The subject was divided into two major areas, water quality and water quantity, which are discussed below.

Sand and Gravel

At present, the situation regarding sand and gravel requirements may not demand critical and urgent action, but it appears that future needs will present serious problems. There are several aspects of sand and gravel offshore mining which should be taken into consideration in reviewing federal program support to the Great Lakes. Four topics for federal research consideration are listed in Table 1. Among these are, first, a need to determine more definitely the long-term requirements for all purposes, including construction, beach fill, off-shore terminal construction, etc. for the Basin; second, the need to appraise or prepare an inventory of sand and gravel resources available under the waters of the Great Lakes; third, the consideration of a program to study the environmental impact of offshore sand and gravel mining; and fourth, development of improved wind and wave forecasts and climatology to support the environmental sensitivities of mining operations on the Great Lakes.

Other Mineral Resources

The mineral resources of the Great Lakes are not well identified at this point. Mining in the coastal zone has included operations for copper, iron, salt, and building sands on the U.S. side and oil and gas on the Canadian side. The only known offshore mining operations have been for sand and gravel and, under the lake bed, for salt. Recent interest has been shown, however, in deposits of ferro-manganese oxide precipitates both in Green Bay and in Lake Ontario and in possible extensions of the native copper deposits of the Keweenaw Peninsula under Lake Superior. The potential for additional mineral discoveries is quite high.

Present federal programs do not appear to address the problems of lake mineral resource inventory (Table 1). This should be included in the national mineral resources programs as a matter of course. In anticipation of mining operations for commodities other than sand and gravel, examination should be made of the potential impact of alternative extractive methods on lake environments. Predictive models are required to assess environmental impacts. Some preliminary studies have been made on specific deposits through Sea Grant-funded programs, but these have been based on very speculative resource data. No matter what approach is taken, the first order of priority for additional federal effort is the identification of the resource.

Shoreline Resources and Beach Modification

The 3700 miles of United States shoreline on the Great Lakes are a unique natural resource of national importance. The problems of the shoreline zone are complex and interrelated and require increasing amounts of planning and research. About 1300 miles are subject to significant erosion with 200 miles subject to critical erosion. Flooding from high lake levels is a problem along 200 miles of the shoreline. While much information has been collected on the shoreline resource as it relates to state and federal agency programs, a coordinated and systematic planning and research program is clearly needed.

Table 1: Nonliving resource categories and topics recommended for increased federal effort

Sand and gravel	• Requirements definition • Resource inventory • Environmental impacts assessment • Environmental effects on operations, wind and wave forecasts
Mineral resource (other than sand and gravel)	• Resource inventory • Economic processes for mining • Environmental impacts on lakes • Environmental effects on operations
Shoreline/beach modification	• Shore processes (physical changes, sediment, currents, wind-wave climate) • Coastal erosion • Lake levels • Water quality

Four topics for federal research emphasis are listed in Table 1. The major research needs concern shore processes–sediment and sediment transport, currents, wind and waves, and the effects of high lake levels. Predictive models are required to evaluate the effects of natural forces and man-made changes on the resource values. Future research should be undertaken on a fully coordinated basis. In addition to the states, the federal agencies with interest include the Corps of Engineers, USGS, EPA and NOAA. Special studies are needed to assess the effects of shoreline modifications on environmental values in the shoreline zone.

Water Quality

Water quality is vital to human needs and to a balanced, ecologically stable environment. Water quality is affected by various pollution sources such as wastes, runoff, shoreline erosion, dredging, tailing from mining operations and atmospheric fallout or washout. Three broad aspects of the problem of protecting water quality are shown in Table 2.

1. Prediction of pollution concentration, distribution, and effects–The ability to predetermine the concentration, distribution, chemical and biological interactions, and effects of pollutants is important to areas of the Lakes. Existing federal programs address this problem, but additional efforts are considered necessary.
2. Establishment of criteria–Establishment of water quality criteria is an immediate need of the Great Lakes region. A response to the immediate requirements of the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500) most likely will not fulfill all requirements in this area. Multifaceted mathematical models will be required to evaluate the worth of the initial criteria. While overlap of agency programs is not considered a significant problem, coordination of diverse agency programs will speed up the process.
3. Monitoring–This portion of the water quality needs includes collection of data to support the efforts both in model development and testing, establishment of criteria and evaluation of results of water quality management. Existing data is not adequate to make the types of determination society is demanding. It appears that a good central data bank for water quality information would facilitate many of the agencies' efforts in this field.

Table 2: Water resources categories and topics recommended for increased federal effort

Water quality	• Prediction of pollution concentration distribution and effects • Criteria establishment • Monitoring
Water quantity	• Prediction of lake levels • Lake levels management • Monitoring

Since data are derived from most federal agency programs, stronger coordination of data storage and management is clearly indicated.

Water Quantity

Three main problem areas related to water quantity are outlined in Table 2. These are: prediction of lake levels, lake level management, and lake level and hydrologic monitoring. In each of these areas, the current federal research program is inadequate. Increased research is necessary in hydrologic parameters, such as groundwater and precipitation; in deterministic and stochastic modeling for the Great Lakes System; in the development of water quantity forecast techniques; in the development of regulation plans to provide for the optimal use of the Great Lakes Water resources. Increased federal support in each of these areas is desirable. However, there must be better coordination among the federal agencies involved in hydrologic studies and research on the Great Lakes. It is recommended that this coordination be established by an informal committee composed of the major agencies active in this area to identify gaps and avoid possible overlap.

* * *

Power and Energy

Panel Participants

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Howard Zar**	Region V, Environmental Protection Agency

*Chairman
**Agency Prime Discussant

The panel on power and energy directed most of its attention to what it considered to be research needs or gaps in the broad areas of environmental impact of power plant siting. A major portion of the discussion focused on the problem of thermal effects. Agency missions were not discussed, but the research coordination efforts of the OST Interagency Committee on Water Resources Research was noted, particularly in the area of thermal pollution. The panel recommends that additional data, research, and/or analyses are needed in the following areas.

Thermal Effects

1. Ecology
   a. Biological effects of entrainment of microorganisms through cooling

    systems—impacts on species, aquatic populations, and fisheries resources; development of systems to minimize adverse effects.
    b. State-of-the-art on design of cooling water intake and discharge structures to minimize impingement and entrainment; evaluation of velocity structure near cooling water intakes.
    c. Ecological criteria (terrestrial and aquatic) for selection of power plant sites, including cooling water intake and discharge facilities; establishment of criteria for what constitutes "significant adverse impact or damage."
    d. Effects of sublethal temperature and other environmental stresses on important species through the life cycle, i.e., rate changes, cold shock, and behavioral response.
    e. Field studies of total ecosystems in the vicinity of large plants—plankton, periphyton, benthos, and fish; assessment of present lake-wide effects.
2. Thermal plume models
    a. Field verification of existing temperature prediction models in vicinity of large power plants located on lakes, streams, coastal areas, and estuaries.
    b. Intensive effort to obtain 2- and 3-dimensional ground truth to verify remote sensing techniques for both local and regional impacts of power industry operations.
3. Alternate cooling systems
    a. Impact of wet and dry cooling towers upon local and regional weather modification, including cloud formation, increase of precipitation, increase of fogging and icing, comprehensive field studies.
    b. Development of improved heat dissipation systems, such as dry cooling, to reduce adverse environmental effects of power plants.
    c. Further analysis of the costs of backfitting various alternate cooling systems to existing power plants.
4. Beneficial uses of waste heat
    a. Continued engineering and environmental assessments of the beneficial uses of heated water for agriculture, aquaculture, recreation, and industrial use.
    b. Feasibility of using heated effluents in extending length of navigation season (effects on cold-water ecology); determine effects of the Niagara River ice boom on the environment and surrounding climate.

Power Plant Siting

1. Assess and predict the cumulative and synergistic effects of multiple power plant facilities (radionuclides, thermal, and chemical discharges) upon regional areas, such as the individual Lake basins.
2. Analysis of the impact of radiological accidents on water supply and other uses.
3. Greater consideration of social and aesthetic factors in the siting of power plants as it affects land use and shore access.

Environmental Impacts (Other than Thermal) of Power Plant Effluents or Energy Consumption

1. Analysis of the impact of alternative means for ash handling and disposal.
2. Stack gases—fallout of gaseous and particulate emissions such as selenium, mercury.
3. Energy consumption by other industries, e.g., steel, oil refining, effluent problems.
4. Effects of biocides and chemical blowdown.
5. Effects of hydroelectric power operation.
6. Analysis of the impact of alternative means for the transfer and storage of fuels and power.

* * *

Living Resources

Panel Participants

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William Brungs**	Office of Research and Monitoring, Environmental Protection Agency
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Carl Lorenzen**	National Science Foundation
Dr. Andrew Robertson**	National Oceanic and Atmospheric Administration, Department of Commerce
Dr. Stanford Smith	Department of Commerce

*Chairman
**Agency Prime Discussant

The prime discussants and participants on the living resources panel recognize the complexity and magnitude of the various programs and activities concerned with the biota of the Great Lakes and stress the necessity of establishing baseline data to coordinate these programs and activities.

Knowledge of present conditions and trends and the ability to predict future conditions under pressures of growing population and development is needed in order to guide and manage commercial and sport fishing activities and to influence development decisions and planning alternatives to preserve the health of the Great Lakes and their living resources.

Potential areas of duplication may exist where more than one agency is working on environmental impact, federal aid, thermal pollution, environmental contaminants, remote sensing, and coastal processes. Despite this, the problems are so large that the likelihood of unnecessary duplication is minimal.

Therefore, it is recommended that federal representatives concerned with the living resources of the Great Lakes should initiate priority programs in the following areas:

1. Documentation of present knowledge concerning species composition and its quantitative significance.
2. Long-term quantitative inventory of the Great Lakes biota.
3. Biological mapping of the Great Lakes shoreline.
4. Interaction studies, particularly trophic interactions.
5. Life history studies of significant species.
6. Research that would permit meaningful estimation of the impact on lake populations of various uses of Great Lakes resources.
7. Data coordination and availability.

* * *

Navigation and Transportation

Panel Participants

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C. Fred Jenkins	National Oceanic and Atmospheric Administration (NOAA), Department of Commerce
Max W. Mull	National Weather Service, NOAA, Department of Commerce
James Saylor	Lake Survey Center, NOAA, Department of Commerce
Tudor T. Davies**	Office of Research & Monitoring, Environmental Protection Agency
Herman Mark**	National Aeronautics and Space Administration
Lt. Thomas Brennan*	Ninth Coast Guard District, Department of Transportation

*Chairman
**Agency Prime Discussant

The purpose of the discussion of the panel on navigation and transportation was to consider the adequacy of the present federal marine science and engineering program on the Great Lakes within the scope of this topic.

Federal programs associated with navigation and transportation on the Great Lakes were described in individual agency presentations and they are noted and listed herein. These on-going programs and the authorized studies for which the represented agencies are primarily responsible provide the framework for discussion. Major system navigation studies underway by the federal government include the following:

1. Extension of the season beyond the present eight months.
2. Need for additional locks on the Seaway.
3. Deepening connecting channels and harbors.
4. Need for an All-American Canal between Lakes Ontario and Erie.

5. Containment of all polluted dredged material for a period of ten years.
6. Continuing maintenance and operation of existing facilities.
7. Studies of the modes, rates, regional harbors, traffic patterns and congestion, changes in vessel fleet, and system economies.

Panel participants also agree that on-going, independent research efforts by federal agencies, which on the surface may indicate a duplication of effort, do not, in fact, overlap when examined more closely. The missions and roles of the various agencies tend to provide a balanced base for augmenting areas of investigation oriented to distinct fields of interest, so that their efforts are complementary rather than duplicative.

In view of these general conclusions, panel participants suggest that the important system-wide on-going and planned navigation and transportation program provides both an opportunity and a basis for coordinating and developing agencies' effort on the Great Lakes. Research effort will be needed to support development of lake regulation, shore protection and further improvement of commercial navigation and transportation being carried out by responsible agencies. It is recognized that one agency will have primary responsibility for a project or operation. However, input and assistance is invariably required of the others.

Agencies involved in these cooperative efforts include, but are not limited to, the Department of Defense (Corps of Engineers), Department of Transportation (Coast Guard), Department of Commerce (National Oceanic and Atmospheric Administration, and Maritime Administration), Environmental Protection Agency (EPA), and National Aeronautics and Space Administration (NASA).

Projects include channel, lock and harbor maintenance and improvement, establishing and maintaining aids to navigation, providing charts and other navigational information, obtaining and disseminating weather and ice information, monitoring and regulating vessel traffic, lake regulation, pollution, customs, and improving vessel design and navigational systems. Participants find that, as a rule, much of these efforts are in fact coordinated at the working level in day-to-day operations. However, many efforts, particularly those designed to improve navigation, require more complex and higher level coordination. Recognition of the need for this cooperation at the Department level is essential to its effective operation, both in day-to-day and in large-scale applications. Panel participants note that such coordination is being effected in many instances. The Great Lakes-St. Lawrence Winter Navigation Demonstration Program is a good example of such coordination. Others are the Great Lakes Water Levels Study, under the International Joint Commission and the International Field Year for the Great Lakes.

Future Development

Present studies in navigation will undoubtedly lead to some degree of development. One far-reaching improvement would be extended season navigation, which would affect virtually all interests on the Lakes. Present coordination among agencies should be continued and expanded to assure planned understanding and development in the best interest of all uses.

Similarly, considered channel deepening, the possible All-American Canal, and considered twinning of the Seaway locks all would have great impact on the economy and on other interests. These programs should evolve through cooperative efforts of responsible agencies, appropriately coordinated by the lead agency to utilize their capability. Such involvement will insure that all impacts, costs and benefits are considered in any future construction.

Research Need and Recommendations

It is recognized that each agency has a need to acquire data from the Great Lakes in carrying out its mission. It is considered virtually impossible for agencies to mount a sustained research effort without a platform for data acquisition. As a basic tool for such a data platform, a research vessel for use on the Great Lakes is required by all agencies and endorsed by all agencies. The panel participants recommend that a research vessel be provided for the Great Lakes. The vessel must be available on an equitable basis, but operationally controlled by one agency. The research vessel would support the acquisition of knowledge necessary to develop adequate capability for efficiently and economically solving multi-discipline problems of the Great Lakes as required by agency missions.

The panel also recommends that coordination of research planning and activities of agencies be a prime goal of the Interagency Council on Marine Science and Engineering.

* * *

Recreational Needs

Panel Participants

Name	Affiliation
John Housley**	U.S. Army Corps of Engineers
Max W. Mull	National Weather Service, National Oceanic and Atmospheric Administration, Department of Commerce
W. Monteith**	Lake Survey Center, National Oceanic and Atmospheric Administration, Department of Commerce
Chris Noe	National Oceanic and Atmospheric Administration, Department of Commerce
Thorndike Saville, Jr.**	Coastal Engineering Research Center, U.S. Army Corps of Engineers
Howard D. Tait*	Bureau of Sport Fisheries and Wildlife, Department of the Interior
Nelson Thomas**	Office of Research and Monitoring, Environmental Protection Agency

*Chairman
**Agency Prime Discussant

Many of the research and engineering projects of federal agencies have an obvious impact on the quantity and quality of recreational opportunities available in the Great Lakes Basin. In reviewing the papers that were presented during this conference, the panel on recreation limited its consideration to recreational pursuits on the Lakes and the near shore areas. The participants agree that recreation is an essential element in the quality of human life in the region, and that the need for high-quality recreational facilities there is growing.

The panel also recognizes that the increasing pursuit of recreation in the Great Lakes Basin is beginning to create problems in itself, since the quality of a recreational experience is affected by the quality of the resource upon which the recreation is based. An increasingly affluent society and the development of extensive highway systems in the Basin has generated great pressure on the recreational resources of the area.

Although the conference itself was not organized to consider the recreational resources of the Great Lakes area, many federal science and engineering programs currently underway are having beneficial effects on recreation. The objectives of most federal programs for the Great Lakes, as described at this conference, are compatible with recreational goals for the area. Current and planned projects to improve water quality of the Lakes will directly increase both the quality of recreation and the supply.

Problems Affecting Recreational Opportunities

The size of the Great Lakes, while offering much potential recreation area, also creates problems in utilization. Large portions of the Lakes are little used because of difficulty of access and hazardous conditions for boaters, fishermen, and swimmers. Expanded use of the Great Lakes to satisfy recreational needs is closely tied to the development of additional boating facilities and improved small boat design. Deteriorated water quality inhibits recreational growth as much as any other factor. Certain Great Lakes beaches have been closed because of polluted waters. Also, soil erosion and sedimentation in the Basin, disposal of dredge spoils, thermal pollution, solid waste disposal, and air pollution all affect the quality of recreational experiences and limit their availability. Problems include competing land use and the availability of and access to beaches, highway congestion and overuse of beaches and shoreline parks, and the environmental disturbances of all-terrain vehicles. Fish population imbalances and low fish productivity also adversely affect sport fishing on the Great Lakes, while the contamination of beaches with dead fish continues to be a problem.

Planning for Recreational Needs

The panel discussants formed the opinion that even though there are several federal agencies conducting activities related to recreation, no overall national plan for meeting recreational needs is apparent either individually or collectively among the federal programs reported at the conference. The programs did not seem to reflect an awareness of existing major recreational planning efforts for the Great Lakes Basin. The panel therefore concludes that the status of planning for recreation in the Great Lakes Basin needs to be determined and such materials as are available should be incorporated into agency program planning to a greater degree than was apparent at the conference.

In retrospect, the panel members believe that the paper presented at the conference by Frederick O. Rouse which outlined the planning role of the Great Lakes Basin Commission deserves careful reading by all conference participants. The paper views the water and land resource needs of the next 50 years and projects areas where research programs can assist in meeting these needs.

In order to collate research, additional planning studies, data collection and analysis, and areas for further intensive investigations, the Basin Commission has underway a framework study on use, conservation, and development of water and related land resources during the next 50 years. The study includes a main report and 24 appendixes, each devoted to a specific research topic. At this time, some of the appendixes, including No. 21, "Outdoor Recreation," are in final draft and others are being revised following comments by the Commissioners and planners. The recommendations in these appendixes will be sifted, analyzed, and presented by the Commission in its final report.

Followup Action

The panel recommends that managers of all federal programs concerning the Great Lakes participate in another program review conference with emphasis on recreation subsequent to the release of the Great Lakes Basin Framework Study. The Bureau of Outdoor Recreation, Department of Interior is suggested as an appropriate agency to provide leadership in this continuing effort.

The U.S. Geological Survey in the Great Lakes Basin

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ABSTRACT

The U.S. Geological Survey came into being by Congressional Act on March 3, 1879, with responsibility for classifying the public lands and examining their geologic structure and mineral resources. Under this broad charter the Survey's work now approaches the first-century mark with rapidly expanding coverage on mineral resources, topography, surface and subsurface geology, and water resources.

In the Great Lakes Basin the Survey has mapped about 90 percent of the area in standard 7½- or 15-minute topographic quadrangle formats. Mapping is underway for the remaining 10 percent of the area, with completion expected by 1975. In principal metropolitan areas the Survey maintains a five-year cycle of map revisions.

The Survey continues its geologic quadrangle mapping to update its earlier mineral-resource appraisals, identify new targets for exploration, and provide geologic information for multi-purpose uses. Presently, emphasis is on Michigan's iron-range country, copper districts, and on geochemical prospecting in the eastern upper peninsula of Michigan.

The Survey continues its assessment of the surface and underground water resources. In all eight Great Lakes Basin states this work is funded jointly by the Survey and various state and local cooperating agencies. This fiscal year the total budget is about $2,000,000. The work is to define the physical characteristics of individual river basins and aquifer systems, laying foundations for the inevitable needs to model various tributary surface and subsurface parts of the basin.

Since 1956 the Survey has maintained a nationwide program of basic research, seeking better definition of hydrologic processes in order to fill gaps in the fundamental knowledge of surface- and ground-water hydrology and water quality. In fiscal year 1973, over $9,000,000 of federal funds support about 150 research projects and nearly 200 full-time scientists.

Knowledge and investigative capabilities applicable to a host of hydrologic problems flow from the research program. A few examples are especially pertinent in the Great Lakes Basin.

First, mathematical models with digital-computer solutions describe in a two-dimensional areal sense the dynamics of water movement and transport of

any constituent pollutant in surface-water bodies. These models can be applied to selected segments of the Great Lakes, such as bays or river mouths, as local problems of thermal, chemical, or sediment pollution challenge analysis.

Second, two-dimensional mathematical models with digital and analog solutions describe the dynamic movement of fluid and the dispersion of any constituent pollutant in aquifer systems. These models can be applied to aquifers in the basin, as local problems of water development and pollution materialize.

Third, water sampling and existing analytical techniques can be applied to define in three dimensions the magnitude of the stable sulfur isotope ratio S^{34}/S^{32} in each of the Great Lakes. Results should yield important knowledge on sources of various sulfur-related pollutants and on internal circulation patterns in the Lakes.

Fourth, because evaporation from the Great Lakes themselves is such an important hydrologic parameter, the prospects for its more precise definition might be greatly enhanced by measuring changes in the horizontal flux of moisture vapor near the air/water interface across suitably instrumented fetches of Lake surface, when wind speed and direction remain stable.

The Survey's future activities in the Basin will continue to emphasize appraisal of the water resources and analysis of a broadening complex of problems accompanying the mineral and water development. The basic research effort will continue, and many of the very real opportunities for applying the knowledge gained will hinge upon collaboration with other federal agencies whose missions are more specifically oriented to the Great Lakes Basin.

* * *

INTRODUCTION

In June of 1969 the Great Lakes Basin Commission, in consort with the Committee on Multiple Use of the Coastal Zone[1] released through the Government Printing Office a 58-page printed report entitled "Great Lakes Institutions—A Survey of Institutions Concerned with the Water and Related Resources in the Great Lakes Basin." On page 20 of that report the national scope of the U.S. Geological Survey's mission is given briefly and accurately with a few details of the work then current within the Great Lakes Basin.

The present paper, drafted for this first Interagency Committee on Marine Science and Engineering conference on Great Lakes research, features not only an expansion of the earlier and very succinct information, but also special reference to the few selected aspects of the national program of federally funded water research deemed most pertinent to achievement of better overall coordination in planning the total federal program of research on the Great Lakes.

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[1] Established by the National Council on Marine Resources and Engineering Development.

STATUTORY AUTHORITY OF THE U.S. GEOLOGICAL SURVEY

The Geological Survey's basin authorization traces back to a Congressional Act of March 3, 1879 (43 U.S.C. 31). The language in this Act is unusually brief yet broad in scope. It specifies, "... the classification of the public lands, the examination of the geological structure, mineral resources, and products of the national domain." Other legislative and administrative actions over the years have amplified and extended the Survey's functions notably in relation to the emergence of topographic mapping in support of geologic studies.

Authorization for water-resources investigations and research stems from the foregoing general language through Congressional recognition and endorsement, as reflected in amendments to the Act in subsequent years. Thus, the Congressional Act of March 20, 1888 (25 stat. 618), authorized survey of irrigable lands in arid regions, of reservoir sites, and the gaging of streams that might be drawn upon for irrigation. Congress has specifically appropriated funds for gaging streams and performing other functions relating to the Nation's water resources annually since 1894.

Although formal and informal cooperation in scientific investigations has been part of the Survey's fundamental policy since its organization in 1879, Congress recognized the federal-state partnership idea in an Act of March 27, 1928, permitting federal funding of as much as 50 percent of the total required for any cooperative work. Over the years this has been the particular basis for much of the Survey's work program in all eight of the Great Lakes Basin states.

The Geological Survey now approaches the end of its first century of progress with rapidly expanding stores of knowledge concerning mineral resources, and topography, and surface and subsurface geology, and water resources of the Nation.

CURRENT PROGRAM IN THE GREAT LAKES BASIN

To portray the Great Lakes Basin (Figure 1) in topographic map form requires nearly 2,600 standard 7½-minute quadrangle sheets. The distribution of these sheets among the eight Basin states is shown in Table 1. As the table indicates, the Geologic Survey is working on new mapping for about 10 percent (256 maps) of the Basin, and on revisions of earlier maps for another 11 percent (278 maps). The map revision work is scheduled on an approximate five-year cycle and is concentrated in the metropolitan areas. Current revision-work areas include Chicago, Illinois; Milwaukee and Green Bay, Wisconsin; Saginaw and Bay City, Michigan; Erie, Pennsylvania; and Niagara Falls, Rochester, and Syracuse, New York. By about 1975 the Basin will have 100 percent topographic-map coverage in either the 7½-minute (scale 1:24,000) or 15-minute (scale 1:62,500) quadrangle series. However, most of the 15-minute format sheets, which in the aggregate cover about 30 percent of the basin, will then be obsolete or obsolescent.

The Geological Survey is also working on revisions of the following smaller scale maps embracing in part at least, areas within the Basin:

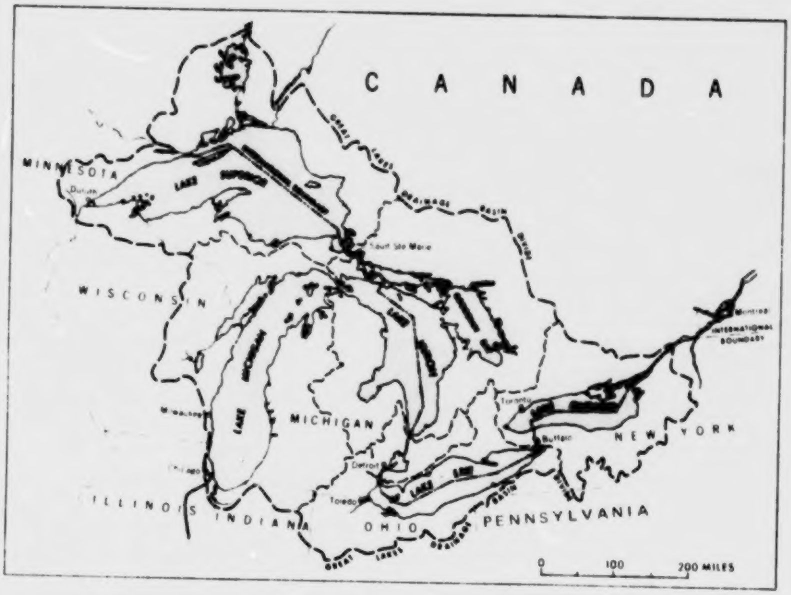
C A N A D A
MINNESOTA
Duluth
LAKE SUPERIOR
Sault Ste Marie
WISCONSIN
MICHIGAN
Milwaukee
Chicago
Detroit
Toledo
Toronto
Buffalo
Montreal
INTERNATIONAL BOUNDARY
NEW YORK
ILLINOIS
INDIANA
OHIO
PENNSYLVANIA
0
100
200 MILES

Figure 1: Great Lakes drainage basin showing subareas of drainage to the individual Lakes.

Table 1: U.S. Geological Survey topographic mapping program in the Great Lakes Basin in 1973

State	Area* of State in basin (percent)	7½-minute quadrangle sheets		
		No. sheets in basin	No. being revised	No. being mapped
Minnesota	11	185	---	3
Wisconsin	36	404	48	65
Illinois	3	35	35	—
Indiana	13	89	8	—
Michigan	100	1162	42	182
Ohio	40	300	67	---
Pennsylvania	4	31	2	6
New York	41	370	76	---
Total		2576	278	256

Based on 7 1/2-minute quadrangle areas.

a. fourteen 1:250,000 scale maps
b. five state base maps, 1:500,000 scale, for Illinois, Indiana, Ohio, Pennsylvania, and New York.
c. three international maps of the world (IMWs), 1:1,000,000 scale, titled Chicago, Lake Erie, and Hudson River.

Joint research is underway in which the Geological Survey and the National Ocean Survey are seeking to improve map portrayal of the Nation's coastal wetlands. Because the legal definitions of wetlands vary among the states and are not consistent with a federal definition, there is a need to develop improved definitions as well as methods of identification. Now being studied are techniques for identifying and delineating wetlands through infrared, color-infrared, and normal color aerial photography. "Orthophotoquads" are then prepared in lieu of conventional line maps for specific areas that are difficult to portray by conventional map symbols. An orthophotoquad is a scale-true photographic presentation on standard 7½-minute quadrangle format, with some cartographic enhancement to identify primary features. Although most of the current research involves only Atlantic coastal areas, the program will be expanded to include coastal areas around the Great Lakes.

Geologic quadrangle mapping by the Geological Survey continues in the Marquette and Gogebic Iron Range country of Michigan and in the Keweenaw copper district of northern Michigan. In the Marquette Range the mapping is refining knowledge of Precambrian structure and stratigraphy to aid in prospecting for and resource appraisal of iron and other commodities. Fieldwork has been completed in the eastern half of the area, and results are either published or in report preparation phase.

In the Gogebic Range mapping provides the base for evaluating both iron and copper deposits, and in the Keweenaw district it defines the origin of and aids in the search for new copper deposits. Fieldwork in both areas is completed, and most studies are in the report preparation stage.

Other aspects of the ongoing geologic study program by the Geological Survey include a regionwide compilation of Precambrian geology in parts of northern Michigan and Wisconsin, impending work on the National Aeromagnetic Map in northern Wisconsin, and a geochemical reconnaissance in the eastern half of the Upper Peninsula of Michigan. This last project involves sampling rocks, soils, and stream sediments to assess the potential of the area for zinc, lead, and copper deposits. Fieldwork began in the summer of 1972, and data collection will be completed in the 1973 field season.

Water resources studies by the Geological Survey are continuing, as they have for many years, in all eight Basin states, financed primarily on a 50-50 basis in cooperation with various state and local agencies. The variety and nature of these studies are evident to some degree in their titles, as listed in Table 2. The list is subdivided to identify activities in specific watersheds of individual Great Lakes. The District office responsible for each study is indicated in parentheses and the Federal/Cooperative funds to support the work in the 1973 fiscal year are shown. The funds have been proportioned to reflect only those parts of the study area lying within the Basin perimeter. Particulars concerning district office contacts, addresses, phone numbers, and working hours are given in Table 3.

Table 2: U.S. Geological Survey water-resources studies in the Great Lakes Basin in 1973

Lake Superior Watershed

Present Studies	Fed. & Coop. Funds '73 f.y.
Flood frequency analysis (Minn.)[a]	$2,000
Flood frequency analysis (Wisc.)	8,000
Low flow frequency analysis (Minn.)	2,000
Low flow frequency analysis (Wisc.)	4,000
Preparation final illustrations, basin studies (Wisc.)	21,000
Water-resources inventory, river basins (Wisc.)	2,000
Drainage areas and river-basin characteristics (Wisc.)	3,000
Ground-water resources, western Upper Peninsula (Mich.)	5,000
	$47,000

Future Studies[b]

Potential for water-resources development, Mesabi Iron Range area (Minn.)
Water-resources appraisal, St. Louis River watershed (Minn.)
Water-resources appraisal, Lake Superior (Minn.)
The red-clay problem in Lake Superior (Wisc.)
Appraisal of inland lakes (Wisc.)

Lake Michigan Watershed

Present Studies	Fed. & Coop. Funds '73 f.y.
Ground-water pollution in Niagara dolomite, Dorr Co., (Wisc.)[a]	$55,000
Ground-water resources of Waukesha County, (Wisc.)	35,000
Ground-water resources of Walworth County, (Wisc.)	30,000
Hydrologic effects of dredging small spring ponds (Wisc.)	12,000
Definition of stream drainage areas (Wisc.)	3,000
Definition of stream drainage areas (Ill.)	1,000
Definition of stream drainage areas (Ind.)	1,000
Flood frequency analysis (Wisc.)	8,000
Flood frequency analysis (Ind.)	4,000
Flood frequency analysis, small watersheds (Ill.)	1,000
Flood frequency analysis, small watersheds (Ind.)	14,000
Flood inundation mapping (Ill.)	3,000
Low flow frequency analysis (Wisc.)	4,000
Hydrology of river-based recreation, glacial terrane (Mich.)	5,000
Water resources, St. Joseph River basin (Ind.)	18,000
Hydraulic characteristics, St. Joseph R. alluvial aquifer (Ind.)	30,000
	$224,000

[a] *Responsible District office.*
[b] *Anticipated within next 5 years.*

Future Studies[b]

Digital model, ground- and surface-water interrelations, lower Fox River area, to analyze water use and pollution (Wisc.)
Digital model, deep sandstone aquifer southeastern Wisconsin, to analyze water-use planning (Wisc.)
Water quality of lakes, Van Buren County, (Mich.)
Water resources of Jackson County, (Mich.)
Water resources of Montcalm County, (Mich.)

Lake Huron Watershed

Present Studies	Fed. & Coop. Funds '73 f.y.
Water resources of river basins in southeastern Mich. (Mich.)[a]	$10,000

Future Studies[b]

Water resources of Livingston County (Mich.)

Lake Erie Watershed

Present Studies	Fed. & Coop. Funds '73 f.y.
Water resources of Washtenaw County (Mich.)[a]	$34,000
Hydraulics of river valleys and bridge sites (Ohio)	4,000
Water plan inventory and hydrologic studies (Ohio)	4,000
Flood hydrology of small drainage areas (Ohio)	2,000
Stream sediment characteristics and yields (Ohio)	6,000
Low-flow characteristics of streams (Ohio)	4,000
Time-of-travel studies of streams (Ohio)	6,000
Flood-hazard information (Ohio)	2,000
Geology and hydrology of western Crawford County (Pa.)	54,000
Deep-well waste disposal (N.Y.)	30,000
	$146,000

Future Studies[b]

Data for managing quality of surface- and ground-water resources (Ohio)
Data for analyzing power-siting problems (Ohio)
Geology and hydrology of Erie County (Pa.)
Flood-plain mapping, town of Evans (N.Y.)

Lake Ontario Watershed

Present Studies	Other Fed. Agency Funds '73 f.y.
Ground-water influx to Lake Ontario (N.Y.)[a]	$15,000
Surface-water inflow to Lake Ontario (N.Y.)	17,000
Soil moisture and snow hydrology (N.Y.)	28,000
	$60,000

[a] *Responsible District office.*
[b] *Anticipated within next 5 years.*

Table 3: U.S. Geological Survey District offices responsible for water-resources studies in the Great Lakes Basin states

Minnesota	
Charles R. Collier, Dist. Chief 1033 Post Office Bldg. St. Paul 55101	Hours: 7:45–4:30 (CST) Phone: (FTS) 612-725-7841
Wisconsin	
C. Lee R. Holt, Jr., Dist. Chief Rm. 200, 1815 University Ave. Madison 53706	Hours: 8:00–4:30 (CST) Phone: (FTS) 608-262-2488
Michigan	
T. Ray Cummings, Dist. Chief 2400 Science Parkway Red Cedar Research Park Okemos 48864	Hours: 7:45–4:15 (EST) Phone: (FTS) 517-372-1561
Illinois	
Davis W. Ellis, Dist. Chief 605 N. Neil St., Box 1026 Champaign 61820	Hours: 8:00–5:00 (CST) Phone: (FTS) 217-356-1137
Indiana	
James L. Cook, Dist. Chief 1819 N. Meridian St. Indianapolis 46202	Hours: 7:45–4:15 (EST) Phone: (FST) 317-633-7398
Ohio	
John J. Molloy, Dist. Chief 975 W. Third Ave. Columbus 43212	Hours: 7:45–4:30 (EST) Phone: (FTS) 614-469-5553
Pennsylvania	
Norman H. Beamer, Dist. Chief 4th Floor Federal Bldg. 228 Walnut St., Box 1107 Harrisburg 17108	Hours: 8:15–4:55 (EST) Phone: (FTS) 717-782-3468
New York	
Robert J. Dingman, Dist. Chief 343 U.S. Post Office & Courthouse Albany 12201	Hours: 7:45–4:30 (EST) Phone: (FTS) 518-472-3107

The information displayed in Table 2 does not include the effort and funds supporting the maintenance of a network of hydrologic data stations. The water-resources studies obligate in total about $500,000 in this fiscal year, whereas the data network obligates a total that is more on the order of $1,500,000. The station types, numbers, and distribution with respect to the individual Great Lakes watersheds are arrayed in Table 4. Obviously, the bulk of this record gathering concerns runoff and water quality in the streams tributary to the Lakes, and stage and water-quality information for the aquifier systems in the Basin.

Part of the hydrologic study program jointly developed by the U.S. and Canada for the International Field Year for the Great Lakes (IFYGL) is to determine the water budget for Lake Ontario. Two important parameters in the budget are surface-water inflow to the Lake and ground-water inflow. Corollary to the latter is the manner in which the ground-water reservoirs contiguous to the Lake are recharged from infiltrating snow melt. The U.S. part of the Lake watershed lies virtually entirely in upstate New York, and thus personnel of the Geological Survey's New York District office were logical choices to undertake examination of the foregoing hydrologic factors under the three "Present Studies" shown for the Lake Ontario Watershed in Table 2. The funds supporting the work have been provided through the National Oceanographic and Atmospheric Administration (NOAA), the U.S. lead agency for the IFYGL program.

Details of the three studies are available through the Geological Survey District office in Albany, New York (Table 3), but they include in brief: (1) enlarging the preexisting collection of stream-flow data so that a more meaningful value can be obtained for this major lake-inflow parameter; (2) improving the definition of the ground-water flow systems in the shallow and deep aquifers bordering the Lake to permit more accurate determination of direct ground-water inflow; and (3) evaluating the manner, timing, rate, and amount

Table 4: Geological Survey Hydrologic Data Network; Number of Stations in 1973

Great Lake	Lake Body		Lake Watershed					
			Streams				Ground Water	
	Stage	Quality	Stage & Discharge	Crest Stage	Low Flow	Water Quality	Stage	Water Quality
Superior	1	1	37	27	49	10	20	11
Michigan	4		156	64	124	40	233	22
Huron			55	26	2		48	
Erie			83	29	47	122	64	2
Ontario			31				39	
	5	1	362	146	222	172	404	35

of infiltration to the watershed soils (mainly in Black River subbasin where snowfall is greatest), with detailing of the subsequent dissipation of the water by evapotranspiration losses and by recharge to the ground-water reservoirs.

Not included in Table 2 are several newly organized and brief one-or-two-year hydrologic studies, funded by the Environmental Protection Agency as part of their National Eutrophication Survey Program. The work entails the straightforward hydrologic definition of the drainage basins for specified lakes that are being sampled for subsequent determinations of nutrient loadings. In fiscal year 1973 funds total about $38,000, distributed as follows among parts of the Great Lakes Basin in the indicated states:

Minnesota	$ 3,000
Wisconsin	5,000
Michigan	15,000
New York	15,000

Also missing from Table 2 are several new hydrologic studies funded by the Department of Housing and Urban Development, relating to their flood-insurance study program. Primary emphasis in the work is on defining the areal extent and elevation of the 100-year flood for the principal streams in specified communities. In fiscal year 1973 funds are expected to total about $49,000, distributed as follows among parts of the Great Lakes Basin in the indicated states:

Illinois	$10,000
Indiana	7,000
New York	32,000

This work is expected to continue for several more years as other communities in the basin are specified. The total funding level will remain about the same or slightly higher.

An in-depth examination of the water-resources studies in the Basin states is not germane to this paper. The work has been in progress for many years and does not change greatly from one year to another. The program is steadily accumulating with time a very detailed fund of basic knowledge concerning the physical properties and characteristics of each stream basin or watershed and each ground-water reservoir or aquifer system. Out of this knowledge will come the building blocks for satisfying the inevitable need to model in some rigorous manner the various stream and aquifer systems tributary to the Great Lakes. Such models, regardless of type, will first require testing and verification of their capabilities to reproduce correctly the historical performances of the stream and aquifer systems. The models may then be used to predict how these systems will perform under various resource management alternatives.

Through the joint funding arrangements with the various State agencies, the Geological Survey keeps well tuned to the current and developing needs in the Basin for geologic and hydrologic information and it guides its investigational program accordingly.

NATIONAL PROGRAM OF WATER RESEARCH

The present broad program of federally funded water research reached formal status in the Geological Survey in 1956. It came into being then largely because field hydrologic investigational demands could no longer be met by incidental research subsidiary to the fieldwork. From its inception the program has been designed to fill recognizable and periodically reassessed gaps in the fundamental knowledge concerning three scientific disciplines: surface-water hydrology, ground-water hydrology, and quality of water. Some aspect of one or more of these three disciplines is inherent in every water resources study, regardless of type or field locality. The water research program, therefore, is specifically designed to support the operating field investigational program. The design transcends the immediate operating needs, however, by recognizing that the more general need is for improved definition of the manner in which the hydrologic cycle functions, particularly as it involves terrestrial water.

Implementation of the water research program has entailed an unending quest for professional talents featuring not only a high degree of formal training in the basic sciences, but also demonstrated individual specialty skills and interests that could be matched reasonably well with selected subdisciplinary areas of needed research. Once recruited, a research worker is granted a substantial degree of freedom, within the limits set by Geological Survey priorities, to design and chart his own course on his research project. Management develops the overall balance of the national program through its choices of the necessary professional talents and expresses and supports its appraisal of research priorities through allocation of funds and personnel positions. The individual research workers, with overview from management, ensure that duplication of effort is avoided.

Accomplishments on the individual projects in the research program are summarized for each fiscal year, in a report titled "Report of Water Resources Research." This report is duplicated annually and given limited distribution by the Geological Survey. In these annual reports the projects are grouped in accord with a classification system outlined by the Committee on Water Resources Research (COWRR) of the Federal Council for Science and Technology. Based on that system, the data array in Table 5 gives some indication of the nature, magnitude, and scope of the national program of water research in the 1973 fiscal year. Predictably, the largest block of effort—more than half the $9,000,000 total—concerns topic areas under the general lable "Water [hydrologic] Cycle." The next-largest block—nearly $2,000,000—labeled "Resources Data," encompasses projects developing better equipment and techniques for collecting, processing, and analyzing all kinds of hydrologic data. The third-largest block—approaching $1,500,000—labeled "Water Quality Management and Protection," embraces projects that include devising techniques for identifying a broad spectrum of pollutants in water, detailing the manner in which they move through stream and aquifer systems and defining their fate.

The nearly 200 full-time research scientists staffing the nearly 150 research projects listed or grouped in Table 5 are housed primarily at four Geological Survey centers at Menlo Park, California, Denver, Colorado, Bay St. Louis, Mississippi, and Arlington, Virginia.

Flowing from the research program is a steady stream of technical reports published by the Geological Survey and in various professional journals, presenting the new knowledge gained. In the aggregate they describe how the results will enlarge and enhance the field of water-resources investigative capabilities. About 80 percent of the program productivity relates directly to improved solutions for a wide variety of practical hydrologic problems. The remaining 20 percent is of a more basic nature and not immediately or specifically problem-oriented.

WATER RESEARCH APPLICABLE IN THE GREAT LAKES BASIN

The results of much of the Geological Survey's national program of water research are applicable either directly or indirectly to solution of problems in the Great Lakes Basin. In this brief paper there have been selected from the great variety of attractive research results several whose potentials for application in the Great Lakes environment are most promising.

Table 5: U.S. Geological Survey National Program of Water Research

Type Activity*	No. of Projects	Full-time Scientists	Federal Funds 1973 FY
I Nature of Water	1	2	$ 53,000
II Water Cycle	86	104	4,639,000
A General	4	5	133,000
B Snow, ice, & frost	4	8	341,000
C Evaporation & transpiration	3	3	147,000
D Streamflow	7	7	666,000
E Ground water	21	26	991,000
F Water in soils	4	6	187,000
G Lakes	3	3	158,000
H Water & plants	5	6	214,000
I Erosion & sedimentation	12	12	511,000
J Chemical processes	17	17	753,000
K Estuarine problems	6	11	538,000
III Water Supply Augmentation, and Conservation	4	7	268,000
IV Water Quantity Management and Control	12	12	815,000
V Water Quality Management and Protection	23	29	1,337,000
VI Water Resources Planning	3	3	75,000
VII Resources Data	14	32	1,929,000
	143	189	$9,116,000

**Categories are those of the Committee on Water Resources Research (COWRR) of the Federal Council for Science and Technology.*

Modeling of Surface-Water Bodies

For more than a decade and a half the Geological Survey has dedicated a significant part of its modest research program to developing general purpose mathematical models of free-surface water bodies. This mathematical modeling effort, initially focused upon providing a faithful description of the dynamics of the water movement in rivers and coastal streams and canals, was later extended to include the more complex flow dynamics typical of well-mixed estuaries and embayments. The work has now progressed to the point of applying to selected estuaries mathematical/numerical models that will simulate the water-flow dynamics, as well as the transport and concentration or dissipation of conservative and nonconservative compounds, or of heat, in the water—all in a two-dimensional areal-through-vertical integration of the basic equations used to describe the movement of the fluid and its constituents. Using a finite-difference numerical process programmed for a digital computer, successive solutions of a particular mathematical model are made with respect to time. In this manner, which may be likened to time-lapse photography, the movement of fluid and constituents throughout the desired time period can be graphically documented in formats such as maps and profiles.

The field data required to activate and calibrate the preceding models include precisely timed water stages continuously recorded at a few carefully selected sites in and around the perimeter of the water body; bathymetric and planimetric information precisely defining the three-dimensional configuration of the water body; meteorologic measurements, such as surface-wind vectors, air temperature, and atmospheric pressure; precise measurements of all significant inflow to or outflow from the water body; and the initial and time-dependent values along the pertinent boundaries of the water body for those water constituents—as, for example, temperature or salinity—whose movement is to be modeled.

Shipboard equipment assembled, developed, and to a large degree already field tested specifically to satisfy stringent specifications for the quick, precise, and relatively easy and inexpensive collection of the requisite large bulk of field data includes a radio range finder (limit 100 km); a digital and analog depth sounder (limit 1,000 ft.); a computer for automatically combining and controlling the flow of data into magnetic tape storage; and a built-in capability for accommodating additional sensors if physical parameters other than water depth are needed. Power requirements for this equipment are of the order of 500 kilowatts.

The two-dimensional mathematical/numerical models have been successfully applied to the analysis of flow dynamics and constituent transport in Port Royal Sound, South Carolina, where the estuarine area modeled is roughly 350 square miles. The model analysis can be used to yield individual predictions over specified time intervals as long as several weeks, of the movement, distribution, and concentration of pollutants hypothetically and successively introduced at each of several individual points in the Sound. The model analysis is described in considerable detail in a paper by Baltzer (1972).[1]

A second and similar application of the models, together with the briefly described data gathering equipment, is now being successfully completed for Tampa Bay, Florida, where the area modeled is also about 350 square miles. The analysis in this instance is yielding predictions on the effects of harbor and ship channel improvements as they relate to local management's range of choices in the placement and shape of dredge-spoil islands, detailing the impact of these choices on circulation patterns that control flushing action and movement of bottom sediments.

Present state-of-the-art in the two-dimensional modeling of surface-water bodies and in the collection and processing of field data therefore is such that field application could be successfully made to a selected segment of one of the Great Lakes where some local problem required a rigorous analysis of the water circulation and movement of dissolved or suspended constituents. Examples might be a need to predict the dispersion of heat or sediment, or some chemical constituent being brought into one of the Lakes by a major stream; or to make a similar analysis for an entire harbor or bay, or an area of a Lake out to, for instance, a depth limit of 50 feet wherein the heat or sediment or chemical constituents are of municipal and industrial origin.

The real challenge, however, of modeling the dynamics of an entire Lake—to the previously described degree of sophistication—lies a bit beyond current modeling capability and also awaits further collection and compilation of pertinent physical data to give an adequate basis for a three-dimensional characterization. The Geological Survey is just crossing the threshold into research development of the needed three-dimensional mathematical models and has recently augmented the work of its own research staff through contract with the Rand Corporation of Santa Monica, California.

In anticipating the capability for applying a three-dimensional model to any one of the Great Lakes, hopefully in the near future, certain basic data requirements are already evident. Paramount among these are the vertical distribution of water density (temperature) and velocity and directions of flow at points located in some suitable gridded-network over the entire Lake, and the wind shear and atmospheric pressure at the Lake surface for a suitable number of the selected points. Data of significant subsidiary importance would include precise volumetric measurements of all major inflows and outflows, determination of reasonable average total values for inflow or outflow across unit segments of the Lake perimeter, and determination of diffusion coefficients in the water body for a range of selected dynamic states.

Modeling of Aquifer Systems

For more than two decades the Geological Survey has pioneered in developing electrical-analog and mathematical/numerical general-purpose models to describe the dynamics of fluid movement through highly complex aquifer systems. The work has progressed from quite elemental analogs, simulating transient flow in one- or two-dimensional aquifers of simple geometry, to the current highly sophisticated mathematical/numerical models capable of describing not only the movement of fluid in aquifers of complex geometry, being subjected to complex programs of water development, but also the concurrent movement and dispersion of constituents in the fluid such as dissolved chemical compounds or heat. Although the mathematical models could be written in a completely general manner to describe the three-dimensional movement of ground water, it generally is most practical and satisfactory to use models that describe the flow in an aquifer system in a two-dimensional areal sense. The third (vertical) dimension is then inherent in the aquifer property termed transmissivity. This property quantitatively expresses the ease with which the fluid moves in accord with any thickening or thinning or other geometrical or physical property change which may occur from point to point in the aquifer. These mathematical models are also "solved" in much the same manner as previously described, namely, by using finite-difference or other numerical techniques programmed through both digital and analog-digital "hybrid" computers. By calling for successive solutions with respect to time, the subject movement of fluid and constituents in the aquifer system can be graphically detailed in formats such as maps and profiles.

Field data required to fill out, test, and calibrate a model appropriate to the analysis of some specific aquifer system include detailed data on thickness and extent of the aquifer and any contiguous fine-grained beds that may allow water to leak into or escape from the aquifer; the head distribution throughout the aquifer and any contiguous fine-grained beds; the manner in which the transmissivity, storage coefficient, and dispersion factors vary throughout the aquifer; and a detailed record of water being recharged to or withdrawn from the aquifer.

In a recent field application of a two-dimensional model to a multiple aquifer system near Brunswick, Georgia, the interrelations between water-level declines, progressive increases in pumping, and the invasion of salt water from an underlying bed were successfully analyzed. Once the historical data were satisfactorily reproduced by the model, the analysis was extended to yield five-and ten-year predictions of chloride distribution in the aquifer system, first assuming no change in the arrays of producing wells, and then assuming intercepting production wells placed between the contamination source and the established well fields. This model analysis is thoroughly described in a paper by Bredehoeft and Pinder (1972).[2]

A two-dimensional mathematical model, solved by digital computer, has also been used successfully in analyzing the problems of managing a combined stream and aquifer system in the South Platte valley of eastern Colorado, incorporating certain economic factors along with the hydrologic. The analysis is very completely covered in a joint paper by Young and Bredehoeft (1972).[3]

If not already at hand, the coming challenge in the Great Lakes Basin is to model the dynamics of fluid and contaminant movement in those aquifer systems that are now or in the future may be active in exchanging water either with streams tributary to the Lakes or directly with the Lakes themselves. Current modeling capability in the Geological Survey could simulate the dynamics of any aquifer system in the Basin and could also simulate the concurrent movement of one or more contaminants or of heat. It seems likely, however, that applications of this capability will need to await some further collection and compilation of the physical data giving complete three-dimensional description to each aquifer system and its boundaries.

Stable Sulfur-Isotope Ratios as Pollution Clues

In its research work under the general label "isotopic hydrology," the Geological Survey has explored the sources, behavior, and fates of selected isotopes in water, convinced that such information would yield clues vital in deducing the history of the water itself. The techniques for dating water in aquifer systems, through collecting water samples and analyzing them for such radioisotopes as tritium and carbon-14, have been well publicized and effectively used. Not so well publicized nor thus far demonstrated through field application are techniques for measuring ratios of stable natural isotopes present in various dissolved constituents in surface and underground waters and how such information can divulge pollution sources, water residence time, and average rates of water movement. The interpretations hinge upon the changes in stable-isotope ratios that may be correlated with environmental events occurring at known historical times and places.

Laboratory facilities now available in the Geological Survey permit analyzing water samples for the natural stable-isotope ratios of hydrogen (deuterium versus protium), oxygen (oxygen-18 versus oxygen-16), and carbon (carbon-13 versus carbon-12). The analytical capability for determining the similar isotopic ratio for sulfur (sulfur-34 versus sulfur-32) is to be added in 1973. This seems to be of special potential application to problems in the Great Lakes Basin.

A reasonable hypothesis is that the sulfate in the Great Lakes stems from several different sources, including precipitation, tributary streams, and ground water, which by one route or another is ultimately delivered to the Lakes. The S^{34}/S^{32} ratios are likely to be distinctive for each of the different sulfate sources. Thus, if water samples are collected at an array of points distributed throughout each Lake and analyzed for sulfate content and isotopic-ratio composition, the results may permit deciphering the sulfate mass balance and attributing correct proportions to each of the various sulfate sources in the Basin. Furthermore, the distribution of the different sulfur isotope ratios in the sulfate in each Lake should reveal significant clues concerning circulation and mixing patterns.

The Geological Survey would welcome the opportunity to participate in a modest joint feasibility study whereby the foregoing approach would be tried on one of the Lakes—say, Lake Superior. The plan would entail collecting no more than several tens of water samples at carefully selected points in the tributary streams as well as in the Lake. The sample volume depends on the sulfate content, but inasmuch as the equivalent of 10-to-20 milligrams of sulfate are needed for the sulfur isotope analysis, usually a one-or-two-gallon size is preferred. The Geological Survey would contribute manpower for sample collection and the analytical work; it would need logistical support, however, for collecting the samples.

Determination of Lake Evaporation

For many years the Geological Survey has pursued research into the mechanics of evaporation from the free surface of lakes and reservoirs. The more rigorous of these studies have been based upon an energy-budget type of analysis in which evaporation is considered as a *vertical* diffusion process, but even this approach leads to known errors that cannot or should not be tolerated in many field situations.

The Great Lakes hydrologic setting and the significance of the evaporation parameter therein seem to offer an unusual opportunity for attempting a proposed new measuring technique, based on fairly simple modifications of the preexisting theory. Such technique might well enhance substantially the precision of definition. The approach would be to measure the change in *horizontal* flux of water vapor near the air/water interface across, for instance, a 5,000-foot reach of one of the Lakes, at a time and place when the wind speed and direction are holding reasonably steady. There is the added stipulation that the indicated wind conditions limit the upward flux of water vapor to a negligible amount.

A pair of instrumented 100-foot masts spaced perhaps 1,000 feet apart would be temporarily anchored at the upwind end of the reach and a similarly instrumented and spaced pair anchored at the downwind end. Inasmuch as the objective would be to determine vapor flux at each end of the reach, the instruments proposed for each mast must yield data for defining the vapor-content and wind-speed profiles from the lake surface up to the 100-foot mast height. Thus, there would probably need to be placed at about 5-foot intervals on each mast an instrument cluster comprising a dry-bulb thermometer, a wet-bulb thermometer, and a wind-speed anemometer. With all instruments recording automatically, the data suite should be ample in only a few hours' time. The entire data-collection system should be portable enough so that it could be picked up and moved to successive suitable sites, thereby permitting the collection of several suites of data.

The analysis of each data suite will yield, by the two-dimensional convective diffusion equation, much-needed insight into the mechanics of vapor transport; the difference between vapor flux at the upwind and downwind ends of the selected reach of lake is the amount of evaporation formula.

The Geological Survey would welcome the opportunity for collaborating with other federal agencies in a field trial of the foregoing proposed technique. The Survey would contribute manpower for data collection and analysis but would need support on the necessary instrumentation and logistics.

Remote Sensing

In a companion paper for this Conference, Morris Deutsch describes in considerable detail the Interior Department's Earth Resources Observation Systems (EROS) program and the Geological Survey's role therein. The particular remote-sensing techniques available for application to research problems in the Great Lakes Basin are also described.

Since July 1970 the Geological Survey and the National Aeronautics and Space Administration (NASA) have collaborated with the Canada Centre for Inland Waters, McMaster University at Hamilton, Ontario, and the University of Guelph at Guelph, Ontario, in a study designed to use remote sensing techniques to identify various hydrologic phenomena in the Lake Ontario basin. The Geological Survey has been monitoring large turbidity plumes at the mouths of the Niagara, Genesee, and Oswego rivers.

To date, the remote sensing techniques have been limited to high-altitude high-resolution aerial photography using black and white, color, and color-infrared films. Four flight missions have been completed by NASA aircraft (in July and October 1970, May 1971, and June 1972), operating at an altitude of about 60,000 feet, covering the south shore of the Lake and a square area about 100 nautical miles on a side that includes the entire western part of the Lake Ontario basin. Although nine flight lines are required to obtain coverage of the 100-nautical mile square, the photography currently provided by the ERTS-1 satellite achieves the same coverage in just one film frame.

Objectives in this work are to study and interpret the characteristics, movement, and dissipation of the large turbidity plumes for as wide a range as possible in meteorologic and river-flow conditions. Toward this end the data collection will continue, taking advantage of both aircraft and satellite instrument platforms. Interpretations of these data are to be keyed to the collection of suitable ground-truth in the land and water areas covered. Results will yield important new definition of Lake currents, diffusion and dispersion patterns, and the fate of sediments entering the Lake.

OUTLOOK FOR RESEARCH WORK IN THE GREAT LAKES BASIN

The Geological Survey anticipates steady continuing growth in the general appraisal studies concerning the surface and subsurface water resources in its cooperative programs with the various agencies in all eight of the Basin states. The information arranged in Table 2 shows specific new appraisals, in prospect in Minnesota, Michigan, and Pennsylvania. It seems inevitable that such appraisals will become increasingly involved with analyzing the consequences of rapidly expanding water use. This means giving better definition to stream and aquifer systems, both independently and conjunctively, as well as to the intrusion of several pollution hazards. The requirements for these much higher orders of analysis can only be met through wider applications of the modeling achievements realized in the research program. The trend is in this direction, and some evidence to this effect is given in Table 2 in the form of the two modeling studies now being planned in Wisconsin.

The Geological Survey will continue its national program of water research, seeking to maintain a steady growth in the stores of basic hydrologic knowledge. No significant changes are foreseen in total federal research funds nor in the number of research personnel. The potential for application of research results to hydrologic problems in the Great Lakes Basin is far greater than described in this short paper, where only a few selected highlights have been discussed. In general, however, the limitations on the Survey's resources are such that help would be solicited from those interested federal agencies capable of providing the logistical support needed to collect some of the pertinent field data. The Survey would welcome opportunities for collaborating with other federal agencies on those hydrologic problems in the Great Lakes Basin that will permit broader field testing and applications of a wide spectrum of water-research products.

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The Role of the Bureau of Sport Fisheries and Wildlife in the Great Lakes

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ABSTRACT

Ecological blunders of man, such as timber exploitation, draining of wetlands, construction of canals and dams, and pollution have been mainly responsible for serious environmental degradation and catastrophic losses of fish and wildlife values in the Great Lakes Basin. Consequently, the major emphasis of the Bureau of Sport Fisheries and Wildlife must be on the protection and enhancement of the Great Lakes habitat—primarily as a single large ecosystem, rather than as a number of political units separated by ecologically meaningless boundaries. By authority of Congress, the Bureau has long been concerned in the Great Lakes region with such diverse activities as establishing refuges for migratory waterfowl, conducting fishery research, evaluating the effects of federally sponsored water resource development projects on fish and wildlife, rearing and stocking of game fish, and assisting the states in fish and wildlife management by giving technical advice and financial assistance. Thus, the Bureau shares a strong common interest with other federal administrative units, as well as with state, interstate, and international agencies, in protecting, enhancing, and ensuring the wise use of fish and wildlife in the Great Lakes Basin.

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The Bureau of Sport Fisheries and Wildlife (BSFW) has important responsibilities for the fish and wildlife resources of the Great Lakes. Perhaps nowhere else in the nation are its activities so diverse and so complicated. Eight Great Lakes states, the federal government of Canada, the province of Ontario, several national and international commissions, and several U.S. federal agencies, including the BSFW, have responsibilities relating to fish and wildlife or have programs which impinge on their welfare. The multiplicity of agencies involved and the occasional confusion about the role of each, the size of the area, and the political complexity combine to make the protection and enhancement of fish and wildlife in the Great Lakes Basin difficult at best. Attainment of goals is further complicated by the inherent relationship between fish and wildlife and their habitat. Every land and water use in the Great Lakes Basin has some effect, good or bad, on fish and wildlife values.

In the interest of communicating information about the responsibilities and programs of the Bureau of Sport Fisheries and Wildlife and with a desire to seek cooperative action on programs of mutual interest, I will attempt to do three things in this presentation. First, I will briefly review the status of fish and wildlife in the Great Lakes Basin and the major problems affecting them. Then I will present a rationale for federal involvement in the conservation of Great Lakes fish and wildlife resources, and finally, I will offer a statement of the Bureau's goals and objectives.

The Status of Wildlife in the Great Lakes Basin

Wildlife and fishery resources of the Great Lakes Basin are valuable national assets—millions of people enjoy fishing and hunting and the presence of wildlife. High quality food fishes come from the Lakes and an abundance of fish and wildlife contributes greatly to tourism and economic stability and development of the area.

And yet many of these valuable living resources have declined to a fraction of their former abundance and others are in jeopardy. The reasons are many and complex but most of the losses can be attributed to the ecological blunders of man.

The early exploitation of timber resources in the Basin began the chain of events leading to today's seriously deteriorated environment for fish and wildlife. With the loggers came devastating wildfires that caused great vegetative changes, soil erosion, and sedimentation of streams. The removal of tree cover allowed the streams to warm, and pollution and dams destroyed spawning grounds or prevented fish from reaching them.

The construction of the Welland Ship Canal was another man-made change that has had far-reaching effects on fishery productivity of the Lakes. The canal allowed the parasitic sea lamprey and the alewife to bypass Niagara Falls and enter the upper Great Lakes. The sea lamprey decimated the stocks of lake trout, whitefish, and most other large fish. And then the alewife took over. It became so abundant that it displaced most other species, and clogged water intakes and fouled beaches during massive spring and summer dieoffs.

Waterfowl habitat has suffered the same fate. Most of the original Great Lakes wetlands that ducks, geese, and shorebirds depended upon have fallen to drainage, landfill, and other competitive practices.

Perhaps man's most pervasive and disastrous ecological blunder is the use of the Great Lakes as a pollution sink. The wholesale contamination of the watershed with chlorinated hydrocarbons such as DDT and PCB's and the dumping of heavy metals are obvious examples. Not only have we lost valuable fisheries to such contamination, but the very existence of some species may be threatened.

Furthermore, the overenrichment of the Great Lakes from municipal, industrial, and agricultural wastes is slowly and surely destroying the capacity of the Lakes to produce the kinds of fish we want. We believe that the water quality of the Lakes must be such that coldwater fishes such as the salmonids and coregonids can flourish. These are probably the only desirable forms that can occupy the cold, deep waters of the Lakes. Without them the overall fish productivity of the Lakes may decline.

With this past history of environmental degradation and the attendant catastrophic losses in fish and wildlife values, the major emphasis of the Bureau of Sport Fisheries and Wildlife today must be on the *protection and enhancement of habitat for fish and wildlife*. Major ecological changes are still going on with the continuing development of the Basin. Channels are being dredged to accommodate larger ships; extension of the navigation season and lake level stabilization are pressing toward reality; and utility companies continue to eye the Lakes as sites for nuclear power plants. Dredging, filling, bulkheading, drainings, and the construction of highways, airports, and shopping centers go on relentlessly, and thus man's ecological impact and, often, blundering continues.

Rationale for Federal Participation

The Bureau of Sport Fisheries and Wildlife has a Congressional mandate to participate in the protection, enhancement and conservation of the fish and wildlife resources of the Great Lakes Basin. This is expressed in such documents as the Fish and Wildlife Act of 1956, the Fish and Wildlife Coordination Act, and the Migratory Bird Treaty Act. But quite aside from the authorizations, there is a compelling need for federal involvement.

The eight Great Lakes states clearly have jurisdiction over the fish and wildlife within their state borders. Exceptions are the federal responsibilities for migratory waterfowl and the Great Lakes Fishery Commission's responsibilities for sea lamprey control. Although state and provincial agencies surely have the competence to successfully manage the fish and wildlife under their jurisdiction, many of the fish stocks of the Great Lakes do not recognize political boundaries. Rather, they migrate freely between states and between the United States and Canada. Differing management goals and philosophies of different agencies make it difficult to develop an overall fishery management and development program for each of the Lakes. Also, the condition of the fish populations is closely related to regional land uses and to the water quality of the Lakes. The success or failure in protecting water quality in one area of a Lake affects the welfare of fish populations in other parts of the Lake, and the conditions in one Lake obviously affect conditions downstream. The problem is best illustrated in Lake Erie, where the states of New York, Pennsylvania, Ohio, and Michigan, and the province of Ontario all are concerned with common fish populations; yet, water quality of the Lake and the fisheries continues to decline.

The conclusion must be that the Great Lakes need to be treated as one large ecosystem. The development of rational, comprehensive plans for the protection and development of land and water resources of the region are beyond the scope of any one state. Therefore, there is need for coordination and leadership from the federal government and groups such as the Great Lakes Basin Commission and the Great Lakes Fishery Commission.

Another reason for Bureau participation lies in the long history of federal involvement in fish and wildlife matters of the Great Lakes. Concern over the fisheries of the Great Lakes was one of the factors that influenced Congress to establish the U.S. Fish Commission in 1871. By 1891, the refuge concept was applied in the Great Lakes area when Webers Pond (Horicon Marsh), Wisconsin, reportedly was established as one of the first refuges in the United States. In 1918, the Migratory Bird Treaty Act was passed and jurisdiction over migratory birds was vested in the federal government in recognition of the interstate and international scope of waterfowl problems. Thus the Bureau of Sport Fisheries and Wildlife and its predecessor agencies have contributed much, particularly in the field of fishery research and management.[1] The public and Congress and the states have expressed a desire for this to continue.

The most persuasive reason for the federal government to be involved in the conservation of fish and wildlife in the Great Lakes lies in the actions of the federal government itself. It is incumbent upon the government to evaluate the effects of a federal or federally licensed project, whether it be the choice of a site for a nuclear power plant by the Atomic Energy Commission, a water quality program of EPA, or disposal of dredged materials by the Corps of Engineers. If the federal government is responsible for a water resource development project or a major land use, then the federal government must be responsible for fully understanding the consequences of that action in all respects, including the effects on fish and wildlife. Congress has made this requirement clear in several laws, not the least of which is the Environmental Policy Act of 1969. Under the Fish and Wildlife Coordination Act the Secretary of the Interior is authorized to assist federal, state, and other agencies in developing and protecting habitat, rearing, stocking, and controlling losses in connection with water use projects developed or licensed by the federal government. The Water Protection and Flood Prevention Act of 1954 as amended has sections related to fish and wildlife as does the Federal Water Recreation Act of 1965. Even the Federal Power Act of 1920 with its legislative history makes it clear the Federal Power Commission would recognize the requirements of fish and wildlife.

There is obvious need for federal resource programs in the Great Lakes, and the Bureau of Sport Fisheries and Wildlife is aggressively pursuing its responsibilities.

Bureau Goal and Program Objectives

The goal of the Bureau for the Great Lakes Basin, which we share with the states and Canada, is to foster the protection, enhancement, and wise use of fish and wildlife resources.

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[1] In 1970 under the President's Reorganization Plan 4, responsibility for the biological research program and for all activities relating to the Great Lakes Fishery Commission was transferred from the Bureau of Commercial Fisheries to the Bureau of Sport Fisheries and Wildlife.

Our primary objective must be greater protection of deteriorating habitats and the control of factors that threaten to destroy fish and wildlife. Thus we are very concerned about the impact of such things as nutrient loading, toxic contaminants, waste heat discharges, dredging, water levels, and extension of the navigation season.

The Bureau's second most urgent objective is to correct fish population imbalances which are seriously depressing fishery productivity of the lakes. The Bureau, working with the states and Canada to enhance productivity, is engaged in sea lamprey control, trout restocking, and fishery research.

(An optimistic note seems desirable here. Sea lamprey predation has been drastically reduced in recent years through a massive chemical control program. The spectacular success of salmon introductions has provided new sport fisheries and a measure of alewife control in Lake Michigan. Lake trout stocks are now at high levels in certain areas in Lake Michigan and Lake Superior due to rigorous control of the harvest, plants of hatchery fish, and lowered sea lamprey predation.)

The Bureau of Sport Fisheries and Wildlife endeavors to help the state agencies with their management responsibilities through research, technical advice, and financial assistance.

The Bureau's enforcement activities serve to prevent overexploitation of desirable species, and help achieve an acceptable level of compliance with laws, rules, and regulations designed to protect fish and wildlife. Although law enforcement is essentially a state prerogative, certain interstate and international protection is needed. Continuity of protection measures must be provided for migratory animals throughout their ranges; cross-border authority must exist to control shipments of diseased, illegal, or illegally taken fish and wildlife; and by national commitment, rare and endangered species must be preserved.

It is important to remember that fish and wildlife are sensitive indicators of environmental conditions and that the decline and extinction of a species often results from changes in the environment. Fish and wildlife species, then, are not only of direct benefit to man, but also serve an important indirect function for man by indicating a deteriorating environment, and thus warn him about preserving his own environment.

I have not said much about the Bureau's specific research program in the Great Lakes. That will be covered in a later paper. I have, however, suggested that fish and wildlife of the Great Lakes Basin are valuable national assets and that there are compelling reasons for federal participation in their protection, enhancement, and wise use. Fish and wildlife habitat protection is the highest priority objective for the Bureau of Sport Fisheries and Wildlife, and thus we have a strong mutuality of interest with other federal and state agencies active in the Great Lakes area.

Federal Great Lakes Fishery Research Objectives, Priorities, and Projects

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ABSTRACT

Fishery productivity of the Great Lakes has declined drastically since settlement of the area. Premium quality fishes of the Great Lakes such as whitefish, lake trout, and walleyes have been replaced by less desired species, The change is attributed to selective overfishing, pollution, and the extreme instability of fish populations. Sea lamprey predation is still a vexing problem but progress is being made in controlling this parasite.

The federal fishery research program with headquarters in Ann Arbor, Michigan, has the objective of providing baseline information, needed in resource use decisions, about the fishes of the Great Lakes. Studies of the habitat requirements of fish are high priority. The program includes fish population assessments, studies of the effects of mercury and other contaminants on fish, thermal effects studies, and general investigation of the impact of engineering projects on Great Lakes fisheries.

The work is closely coordinated with state and Canadian agencies through the Great Lakes Fishery Commission. Four small research vessels and four field stations are utilized with a staff of 90 and an annual budget of about $1.5 million.

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The role of the Bureau of Sport Fisheries and Wildlife in the Great Lakes is twofold. First and foremost, the Bureau fosters the protection and enhancement of fish and wildlife habitat, and second, it lends assistance to the states in interstate and international fishery management.

The biological research program of the Bureau, centered at the Great Lakes Fishery Laboratory (GLFL) in Ann Arbor, Michigan, contributes to both objectives by providing the knowledge required for an understanding of the factors limiting productivity of the Lakes and by continually assessing the status of fish populations.[1]

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[1] From its inception to 1972 Federal fishery research on the Great Lakes has been accomplished by four agencies. The first Great Lakes fishery investigations were estab-

Other research laboratories of the Bureau also have programs concerned with Great Lakes problems. The Fish-Pesticide Laboratory at Columbia, Missouri, is concerned with the toxicity of pesticides to fish. At La Crosse, Wisconsin, and at Hammond Bay, Michigan, sea lamprey control methods are evaluated. Much of the effort relates to the registration of chemicals used as lampricides and to the physiology of the sea lamprey.

Current Status of Fish Populations

The fishery resources of the Great Lakes have been subjected to incredible abuse for more than a century, and as a result the fish populations and fisheries have drastically declined. The principal reasons for the decline are overfishing, pollution, and the invasion of the alewife and the sea lamprey from the ocean.

Recently there have been promising developments which suggest that the combined United States-Canadian efforts are beginning to restore the fishery productivity of the Lakes. Sea lamprey predation is being reduced in the upper Lakes to a level which will permit desired species such as lake trout, salmon, and whitefish to survive and reproduce.

Massive fish stocking programs have established in Lake Michigan large populations of lake trout and salmon which are not only supporting outstanding sport fishing, but may also be controlling the nuisance alewife. Lake trout are once again abundant in Lake Superior and are reproducing. Sea lamprey control has been extended to Lake Ontario, and plans are being formulated for a large salmonid stocking program there also. The yellow perch, which is probably the most important food and sport fish in the Great Lakes, is increasing in Lake Michigan.

The fishery rehabilitation program has been successful so far because large amounts of money have been invested in research, lamprey control, hatchery operations, and because the harvest has been drastically curtailed. The benefits derived in recreation, economic growth, and employment have been large, and the potential for additional benefits is even greater.

In the long run, however, these efforts will be wasted if the deterioration of water quality and other encroachments on fish habitat are allowed to continue. There are disturbing signs that ecological changes are driving some species from the Lakes. In Lake Superior the last substantial stock of lake

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lished under the Bureau of Fisheries at Ann Arbor in 1927, although studies of Great Lakes species had begun even earlier, about 1918. In 1940 the Bureau of Fisheries was combined with the Bureau of Biological Survey into the U.S. Fish and Wildlife Service. In 1956, the Fish and Wildlife Service was subdivided into The Bureau of Commercial Fisheries and the Bureau of Sport Fisheries and Wildlife. Fishery research at Ann Arbor continued under the Bureau of Commercial Fisheries until October 1970. Then, under the President's Reorganization Plan 4, responsibilities for biological research and activities related to the Great Lakes Fishery Commission, were transferred to the Bureau of Sport Fisheries and Wildlife. (The Bureau of Commercial Fisheries became part of the Department of Commerce and was subsequently renamed the National Marine Fisheries Service.)

herring in the Great Lakes is rapidly declining. The abundance of walleyes and yellow perch in Lake Erie fluctuates greatly from year to year, apparently because of unfavorable conditions on the spawning grounds. Toxic contaminants such as mercury and polychlorinated biphenyls (PCB's) are jeopardizing commercial and sport fisheries and may be having as yet unknown effects on the fish themselves. There is increasing evidence that overenrichment with phosphorous and the resulting accelerated eutrophication is destroying fishery habitat in the Great Lakes. Since fish simply cannot survive without oxygen, efforts to reduce nutrient overloading can come none too soon from a fishery point of view.

The immediate and long-term environmental effects of water-use projects on Great Lakes fisheries are cause for urgent concern. The discharge of waste heat from power generating plants into the Lakes and the siting of such plants on the Lakes have serious implications for fish and other aquatic life. The impact of the proposed extension of the navigation season for shipping on the lakes must also be carefully assessed.

The Bureau of Sport Fisheries and Wildlife is, therefore, giving highest priority to studies designed to produce facts needed by fishery managers, planners, and other public agencies to protect the habitat. The work falls naturally into two categories—fish population assessments and environmental effects studies.

Fish Population Assessment Studies

Fishery biologists are systematically sampling with gill nets and trawls to determine the fish population structure of each of the Great Lakes. Four research vessels are involved in this effort, which extends from April to December each year. In addition to fish samples and water quality observations, information is collected about fish life histories, spawning grounds, and nursery areas.

These data permit the evaluation of sea lamprey control and restoration of lake trout populations and provide a basis for developing fishery management strategies. The assessment work also provides baseline data essential in evaluating the environmental impact of various water- and land-use projects. For example, surveys of fish spawning and nursery areas are useful in estimating the potential damage to fish populations of heated effluents from proposed power plants.

In 1972 the GLFL participated in the International Field Year for the Great Lakes (IFYGL) on Lake Ontario by conducting the most intensive fish population assessment ever undertaken on the Great Lakes. This cooperative effort with the state of New York and the Province of Ontario has revealed that a substantial forage fish base of smelt and alewives is present in the Lake. These species should support introductions of salmon and trout, and now that sea lamprey control has been initiated there is exciting promise of new fisheries on Lake Ontario.

Fishery-Environmental Studies

Much of the research effort at Ann Arbor is concerned with the physiological requirements of fishes of the Great Lakes and environmental factors affecting them. Current studies include measurement of temperature effects on the rate of development and survival of eggs and fry of several species, observations of the attraction and avoidance of various temperatures by fishes, and the interaction of the influences of temperature and toxic contaminants.

There is a continuing concern about the possible deleterious effects of channel dredging on aquatic life. In cooperation with the Corps of Engineers, Bureau scientists are looking at the bottom fauna of the St. Marys River before, during, and after blasting and dredging. Particular attention is given to the mayfly (*Hexagenia*) population. Water samples are being analyzed to detect changes in turbidity and in concentrations of phosphorus, selected nitrogen compounds, iron, mercury, and chlorides.

Similarly, cooperative studies are underway to evaluate the environmental effects of the use of waste heat to reduce the ice cover in the shipping channel off the mouth of the Saginaw River as part of the Extended Navigation Season Demonstration Project.

The discovery of mercury in fishes of Lake St. Clair and Lake Erie at concentrations higher than those considered safe by the Federal Drug Administration resulted in sharp curtailment of sport and commercial fisheries. Similarly, high PCB and DDT levels in fish have been responsible for closure of the chub fishery in Lake Michigan and the catfish fishery in Saginaw Bay. Our research is concerned with the effects of mercury, PCB's, and pesticides on fish growth, reproduction, and mortality, with particular attention to the lake trout. The Bureau has done much to document the effects of pesticides on fish and wildlife, and we are continuing to monitor DDT levels in Lake Michigan fish to detect changes.

Future Emphasis

The Great Lakes Fishery Laboratory will continue fish population assessments, with increased effort in the hub area (northern Lake Michigan, eastern Lake Superior, and northern Lake Huron). Ecosystem modeling and the development of fishery management strategies for various fish stocks will also be emphasized over the next five years. Thermal effluents and toxic contaminants will no doubt continue to be troublesome fishery problems in the Great Lakes Basin for some time to come and thus will continue as high priority research matters.

At La Crosse and Hammond Bay research oriented toward the clearance and registration of sea lamprey control chemicals and toward the development of biological control methods will continue to receive high priority.

In the long run, as the states develop their own fishery-management-oriented research programs for the Great Lakes, Bureau research emphasis will shift to broadly based studies of the quality of the living aquatic resources and the condition of their habitat.

Earth Resources Observation Systems Program Research and Plans for the Great Lakes Basin

Morris Deutsch, Research Coordinator, Water
Resources, Geological Survey, Department of the Interior

INTRODUCTION

The Earth Resources Observation Systems (EROS) Program of the U.S. Department of the Interior was established in 1966 under the administration of the U.S. Geological Survey. The major program activity was to gather and use remotely-sensed data collected by satellite and aircraft for application to the natural resources programs of the various bureaus of the Department. The broad regional and frequent repetitive coverage provided by Earth-orbiting satellites, provides a useful resource information system necessary for effective development and management of natural resources. Remote-sensing technology is particularly effective in appraising ever-changing water-resources conditions.

EROS Program activities in the Great Lakes Basin began in 1970. In June of that year, the Hydrology Panel for the Committee on Space Programs for Earth Observations met at the Canada Centre for Inland Waters and reviewed and endorsed proposals for implementing remote-sensing research applicable to the International Field Year for the Great Lakes (IFYGL) Program employing a test site covering 10,000 square miles over western Lake Ontario and adjoining land areas in Ontario and New York state. The broad objective of the IFYGL program is to learn more about the waters of Lake Ontario and the area draining into it, as a basis for better management for large lakes. It was felt that remote-sensing technology would contribute to the IFYGL program synoptic, spectral, and temporal information, unobtainable by conventional means.

The objectives for the proposed multi-applications remote sensing project were as follows:

(1) provide the mutual EROS and IFYGL program enhancement by obtaining: (a) support for EROS with multidisciplinary scientific input from a large cadre of IFYGL scientists, laboratory analyses, and extensive environmental data from the IFYGL observation network, and (b) support for the Field Year with input of repetitive, multispectral, and regional synoptic data from the Earth Resources Technology Satellite-1 (ERTS-1), ERTS-B, and NASA aircraft.

(2) determine environmental parameters that can be identified and measured by ERTS-1 and ERTS-B relating to the types of information needed for solution of ecological problems in Lake Ontario and its drainage basin.

(3) determine usefulness of remotely-sensed data from ERTS-1 and ERTS-B, and high-altitude aircraft collecting analagous data relayed in near real-time from surface monitors, for application in environmental studies and management programs relating to lake meteorology, energy balance, terrestrial water balance, and water movement.

(4) identify potential users of remotely-sensed data and determine their volume requirements for ERTS-1 and ERTS-B data for both scientific and management applications.

The Lake Ontario basin was selected as a test site for research and development of remote sensing techniques for the Great Lakes Basin, primarily because of the selection of the Lake Ontario basin as the site for IFYGL. The area of the test site approximates the area covered by a single ERTS view. The Canada Centre for Inland Waters agreed to provide facilities and ground measurements for the proposed effort and the National Aeronautics and Space Administration (NASA) agreed to provide very high altitude multispectral photography for American and Canadian investigators under provisions of their Space Research and Technology Program. The technology developed and research results will be as appropriate for the remainder of the Great Lakes Basin as they are for the Lake Ontario basin.

To implement this work, the Department of the Interior let a contract with the non-profit Center for Advanced Research and Engineering Design (CARED) at McMaster University, Hamilton, Ontario. CARED provides a scientific and administrative focal point for concerted effort by participating scientists from Guelph and McMaster Universities, the Canada Centre for Inland Waters, the Ontario Water Resources Commission, and future participants.

DESCRIPTION OF EROS AND RELATED PROJECTS AT THE LAKE ONTARIO TEST SITE

Multispectral Photography

In 1965 the U.S. Geological Survey collected color infrared photography over the mouths of the Maumee and Cuyahoga Rivers where they enter Lake Erie at Toledo and Cleveland, respectively. Figure 1 is an infrared photograph of the mouth of the Maumee River where it discharges into Lake Erie at Toledo, Ohio.[1] The dark trace of water represents the relatively clear water discharging from a sewage treatment plant at Toledo. The lighter tone represents sediment-laden water. In color infrared photography, pure water appears dark or almost black. As the water contains greater amounts of sediment and other material that affect the turbidity, the tones become lighter.

The U.S. Geological Survey has a water-quality monitor that records conductivity, dissolved oxygen, pH, and temperature of the river at Toledo. Obviously, unless the intake is in the plume, it is not recording the quality of the river as affected by the effluent from the sewage plant located on the left bank of the river. This provides an excellent example of the value of a point-source monitor recording quantitative data at the surface as an aid for interpreting remotely-sensed spatial data. The imagery portrays the areal distribution of the pollutants, while the monitor provides a basis for making areal quantitative estimates.

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[1] **With the exception of Figures 8 and 9, the illustrations to this paper are black and white reproductions of color originals.**

Figure 2, showing a turbidity plume entering Lake Erie from the Cuyahoga River, is indicative of the applicability of these data in determining effects of river discharge on water-quality in Lake Erie. The potential use of locating water intakes for municipal or industrial use is indicated by inspection of the photography. The sediment plume is probably correlative to a thermal anomaly. Later research and development has made possible the remote measurement of radiance in the thermal region.

The technical objectives of the above-mentioned contract with McMaster University included the delineation of aquifers within heterogeneous continental glacial-drift terrains, detection of structural geologic controls on basin and inter-basin hydrology, and synoptic distribution of physical and biochemical substances within the waters of Lake Ontario. To provide data to the contractor, NASA's Manned Spacecraft Center flew the following missions of its RB-57 aircraft over the Lake Ontario test site: 6 July 1970, 19 October 1970, 29 May 1971 and 5 June 1972. The RB-57 was equipped with a 9-camera multispectral photographic sensing system. The film-filter combinations on some of the cameras were selected in order to provide an aircraft simulation of the anticipated imagery to be obtained from ERTS.

Figures 3 through 6 are examples of color infrared photography taken over Lake Ontario by the Zeiss camera on the RB-57. Figure 3 shows the plume of the Genesee River entering Lake Ontario at Rochester, New York. The shoreline current is to the northwest and the sediment plumes can clearly be seen. This observation is extremely significant in terms of applicability of infrared photography to detect fate of pollutants in water bodies. The surface traces of a submarine sewage disposal point are indicated by the whitish dot on the water east of the Genesee River plume.

Figure 4 is a color infrared view of the western tip of Lake Ontario, including the City of Hamilton, the Skyway carrying the Queen Elizabeth Way, and the Canada Centre for Inland Waters in the north end of the Skyway at Burlington. Here a turbidity plume, presumably from steel mills at Hamilton, can clearly be seen in the Hamilton Harbour. The source, causes, and fate of the plumes northeast of the Skyway need to be investigated. Plumes of this nature may be caused by submarine discharges of ground water, submarine sewage effluents, or turbidity due to shoreline currents. The multispectral photographic data thus provides a wealth of information that can be applied in studies concerning the source, movement, and fate of pollutants.

Figure 5 shows the Niagara River at its point of discharge into Lake Ontario. The differences in turbidity between Lake Erie waters discharged into the Niagara River and the waters of Lake Ontario are clearly seen. The distribution of other, but non-visible, water-quality characteristics is probably also indicated by the tonal anomaly as shown on the figure.

The right-hand portion of Figure 6 shows a phenomenon not known to have previously been observed in inland water. The dark streaks on the right portion of the figure have been tentatively interpreted by Canadian scientists as representing surface traces of internal waves, which are commonly caused by the physical interactions of waters of different temperatures and densities. Data such as these will eventually provide quantitative inputs to hydrodynamic models.

Thermal Imagery

One of the most powerful tools made available to the hydrologist in recent years is the thermal infrared scanning radiometer. An analysis of all of the potential applications of thermal imaging is beyond the scope of this paper. A principal application, however, is the detection, identification, and measurement of thermal changes caused by effluents in surface-water bodies.

Three different New York lake environments within the Lake Ontario basin were studied employing thermal infrared images:

(1) Lake Ontario (shoreline); very large, one of the Great Lakes, rural and urban areas, nearshore ice cover (Figure 7)

(2) Cayuga Lake; moderate size, deep, one of the Finger Lakes, predominantly rural, little ice cover

(3) Onondaga Lake; small, relatively shallow, in an urban setting, subject to major ice cover

For each lake, aerial visible photography and thermal infrared imagery were provided by the U.S. Air Force Rome Air Development Center, and calibrated thermal infrared imagery was contracted commercially as part of a Geological Survey cooperative program with the New York State Department of Environmental Conservation. Imagery was correlated with available water and weather data.

Imagery of the Lake Ontario shoreline, acquired at several times throughout the year, showed contrasts between natural discharges of the tributary streams, artificial discharges, and the Lake proper.

Figure 7 shows discharge from a pond, a powerplant, and the Genesee River into Lake Ontario in Rochester, New York.

The lake studies have shown that thermal radiance variations displayed on qualitative imagery are effective natural indicators of water circulation patterns. However, quantitative imagery (radiometry) is necessary to help assess the proportions of natural and man-made heat inputs, especially to better define the term "thermal pollution." Quantitative imagery also reduces the field work necessary for limnological ground truth. Analysis of such imagery has pointed out the need for calibrating individual in-place temperature sensors and locating them at sites suitable for collecting the water information required.

ERTS MULTISPECTRAL SCANNER IMAGERY

A brief non-technical description of ERTS is contained in the U.S. Geological Survey pamphlets, "Studying the Earth from Space" and "ERTS and EROS."

Figure 8 depicts the sensor array on the satellite, and figure 9 is an outline map of orbital swaths over the United States.

The multispectral scanner on board ERTS has been collecting data over the Great Lakes since the launch of the satellite in late July 1972. Channel 4 (blue-green band) normally provides the most useful data concerning water bodies themselves, because of this band's water-penetration capabilities. Channel 5 (red band) shows the maximum discrimination of land features and is particularly valuable to the geologist and those concerned with agriculture and land use. Channels 6 and 7 are in the near-infrared portion of the spectrum and show maximum discrimination between land and water.

Figure 10 is a black and white photograph of a 70mm image collected by channel 7 of the multispectral scanner on ERTS-1, covering north central New York state. The image has not yet been specially processed for analysis or interpretation. Preliminary inspection of the 70mm data, however, indicates a number of hydrologic and geologic applications of the multi-spectral scanner data, including:

(1) delineation of moisture anomalies

(2) precise definition of glacial drainageways indicating presence of highly permeable surficial drift aquifers

(3) precise areal distribution of surface water (and change with time employing subsequent ERTS data)

(4) delineation of geologic boundaries

(5) definition of geologic structure controlling storage and movement of water in the crystalline rocks in the Adirondacks

Figure 11 is a black and white rendition of an ERTS multispectral scanner color composite showing eastern Lake Ontario, the Finger Lakes area, and adjacent regions of New York state. Most of the detail provided by the color and the separate bands of the multispectral scanner are obscured or lost in preparing this print for publication in black and white. The original data, however, provide an excellent basis for the analyses listed above and for preparation of the thematic data products described below under "Remote-Sensing Research and Development Plans."

The western half of Lake Ontario is shown on Figure 12, which was also copied in black and white from a high resolution, high contrast color composite from three of the channels of the multispectral scanner. Original data such as these can be used to detect sources, movement, and dispersion of sediment or pollution plumes entering Lake Ontario. The turbidity plume at the mouth of the Welland Canal is depicted here. The plume of the Niagara River is indicated by a clear (dark) area in the turbid (lighter) area of Lake Ontario water. Industrial pollutants in Burlington Bay at Hamilton, Ontario, are clearly evident. On the land surface, discharging ground water along the Niagara Escarpment is depicted by the band of luxuriant (dark) vegetation east of Hamilton on the Niagara Peninsula. On the original data, land-use patterns, moisture anomalies and other phenomena described above can be detected and analyzed.

REMOTE-SENSING RESEARCH AND DEVELOPMENT PLANS

Most of the activities described above are still current, but are scheduled for completion during fiscal year 1974. It is planned, therefore, that the work in progress will be compiled into a descriptive analytical report. The report will be an illustrated exposition of the features studied at the Lake Ontario test site and special applications test sites within it. The report will include most, if not all, of the following thematic data products derived from remotely-sensed data:

- physiography
- topography
- bedrock geology
- pleistocene (glacial) geology
- ground-water potential
- vegetation regions
- climatic zones
- soil moisture conditions
- cultural impact
- lake conditions
- proposed hydrologic data network
- surface-water distribution

It is planned also to produce color photo mosaics for limited areas of the test site showing seasonal changes of features observed in limnological, ground-water discharge, and soil studies. Analyses of RB-57 and ERTS imagery for limnological applications and internal wave analyses are planned for the Lake Ontario portion of the test site. The location, extent, and physical significance of sediment plumes will also be studied.

Further planned research activities over the land portion of the test site include analyses of RB-57 and ERTS data for interpretation of soil and soil-moisture conditions; distribution and water-supply; significance of ground-water discharge; and relations between drainage characteristics, soil types, geology, and soil moisture. The hydrologic and soil-moisture significance of changes in snow cover are scheduled for analysis. The same data will be analyzed also for applicability for basin hydrological monitoring and management as well as for design of a ground-data network needed for eventual basin-wide modeling.

Preliminary planning calls for the Lake Ontario test site to be employed for purposes of defining parameters and sensor, platform, and communications requirements for about a decade, by which time it is hoped that modeling of water-flux and quality will be operationally feasible. Consideration is now being given for employing the Space Shuttle as an experiment platform in this regard.

It is expected that early in 1973 Manned Spacecraft Center will provide an overflight of the Lake Ontario test site by the RB-57 in order to obtain multispectral data coverage under winter conditions. Weather and scheduling permitting, the flight will coincide with an ERTS overpass of the test site. Planning is underway for NASA's P3A aircraft to obtain passive microwave imagery of selected ground swaths, also at the same time. Figure 13 is a black and white copy of a color-enhanced passive microwave image of Lake St. Clair and adjacent areas in Michigan and Ontario collected by NASA's CV-190 aircraft on March 20, 1972. The microwave radiometer operated at a frequency of 19.35 GHz (1.55 cm). On the color copy, thin ice on the Lake is shown as blue; thicker ice as green and yellow; and so-called snow-ice as orange and red. Land areas at Detroit appear as orange and red, but the portion of Ontario shown east of Windsor was extremely wet, resulting in lowered emitted microwave radiation at the sensor frequency. Figure 14 is a black and white copy of the snow and ice classes detected and delineated by the imaging radiometer.

Data collection is for a variety of program requirements: an ice dynamics experiment being carried out jointly by NASA, the U.S. Geological Survey, and the Canada Department of the Environment; research in hydrologic applications by Lewis Research Center, NASA; IFYGL; preparation for a Skylab experiment employing microwave radiometry for analyzing lake and sea ice dynamics in Lake Ontario and the Gulf of St. Lawrence.

In the past, remote observations of hydrologic parameters have been obtained with sensors operating in the visible and infrared portions of the spectrum. These data have been available principally in desert regions for targets not obscured by clouds, vegetation or soil. However, the most dynamic changes in the distribution of water occur during cloudy conditions when visible and infrared sensors are ineffective. Microwave sensors functioning at considerably great wavelengths in the electromagnetic spectrum are operable under adverse weather conditions and provide a direct measure of significant water equivalent. Distinct possibilities exist to automatically record and process the data electronically. Microwave sensors present a unique opportunity to make parametric inputs which were not hitherto possible to hydrologic models.

Considerable progress in remote-sensing technology applicable to earth-resources programs in the Great Lakes Region has resulted from the collaborative studies of the Geological Survey and NASA. Further collaboration, particularly with NASA's Lewis Research Center, will most likely result in technical advances of great potential benefit to water managers in the Great Lakes Region.

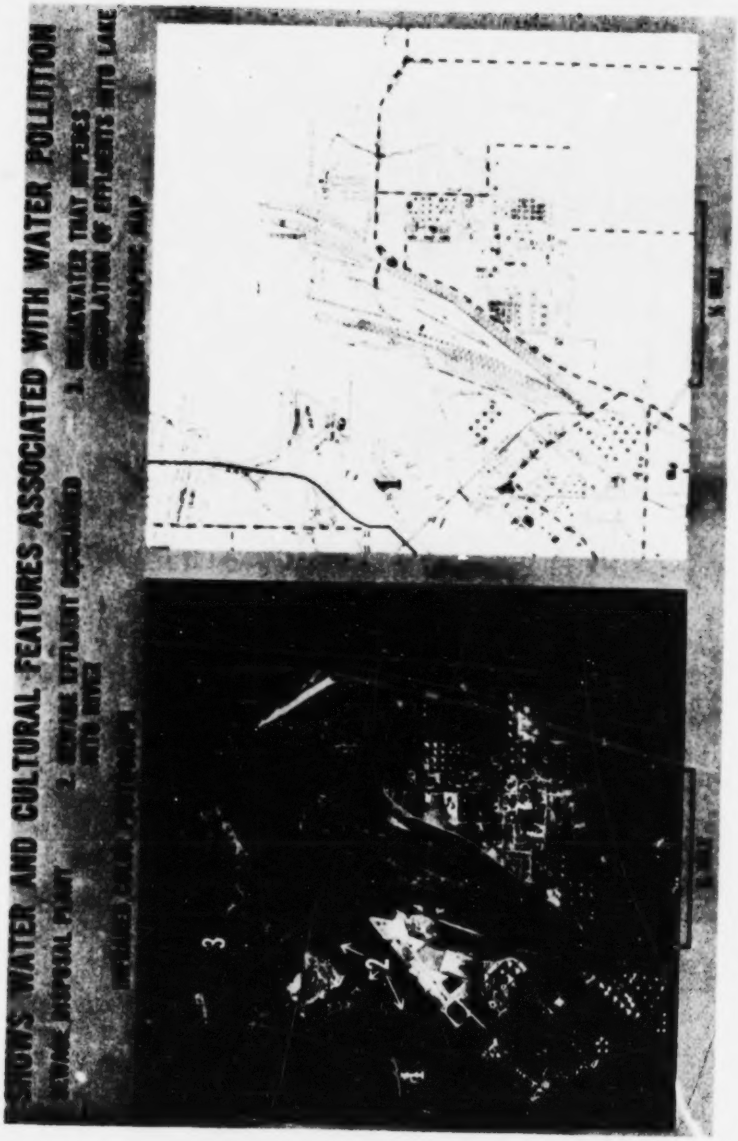
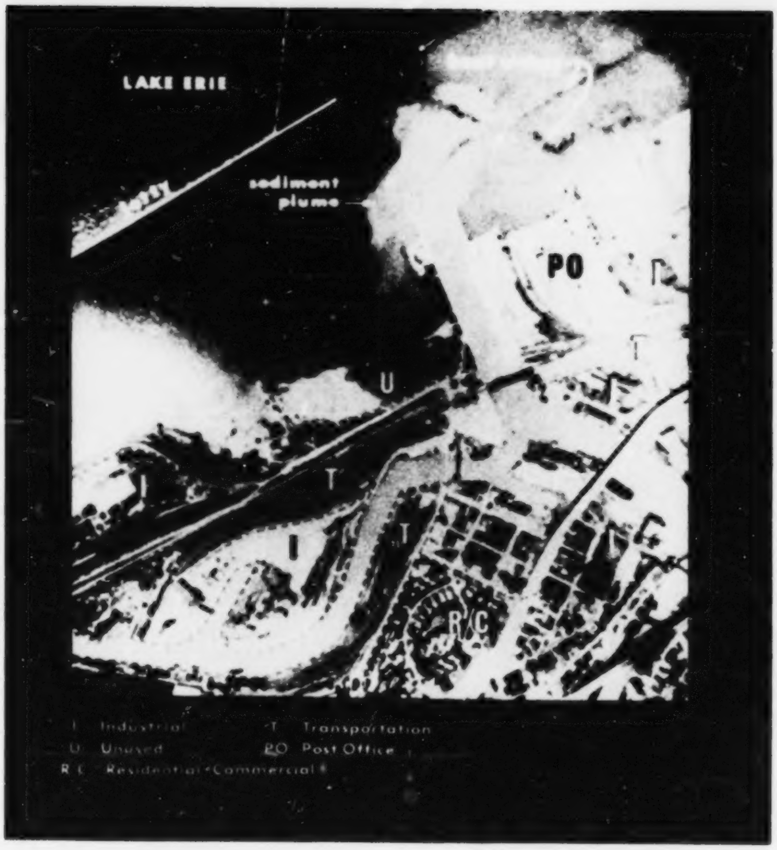

SHOWS WATER AND CULTURAL FEATURES ASSOCIATED WITH WATER POLLUTION
SEWAGE DISPOSAL PLANT
2. SEWAGE EFFLUENT DISCHARGED INTO RIVER
3. BREAKWATER THAT IMPEDES CIRCULATION OF EFFLUENTS INTO LAKE
TOPOGRAPHIC MAP
½ MILE
1
2
3

Figure 1.


LAKE ERIE
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I Industrial
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U Unused
PO Post Office
R C Residential-Commercial

Figure 2.

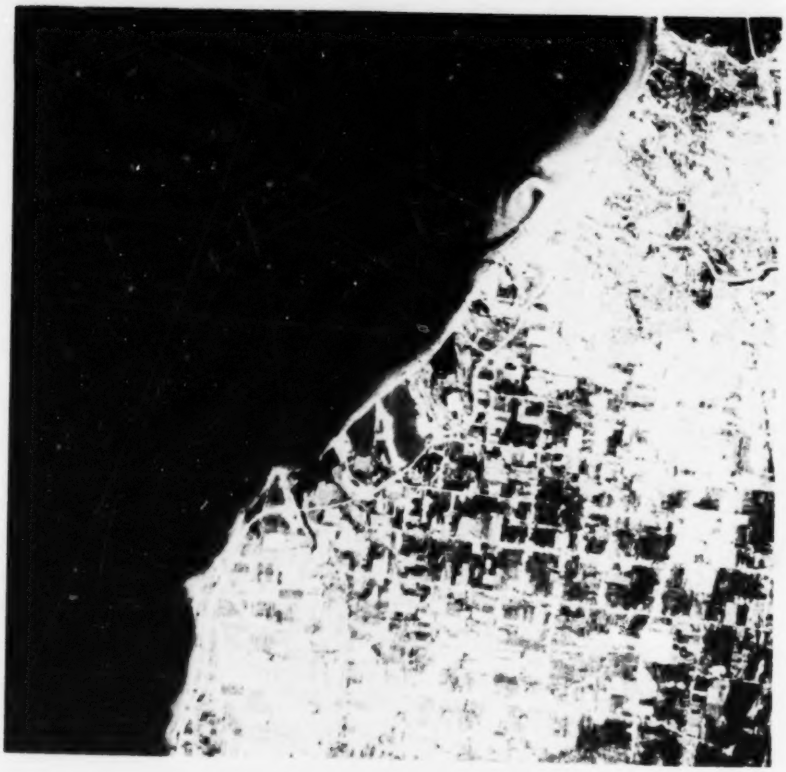

Figure 3.

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best available copy.

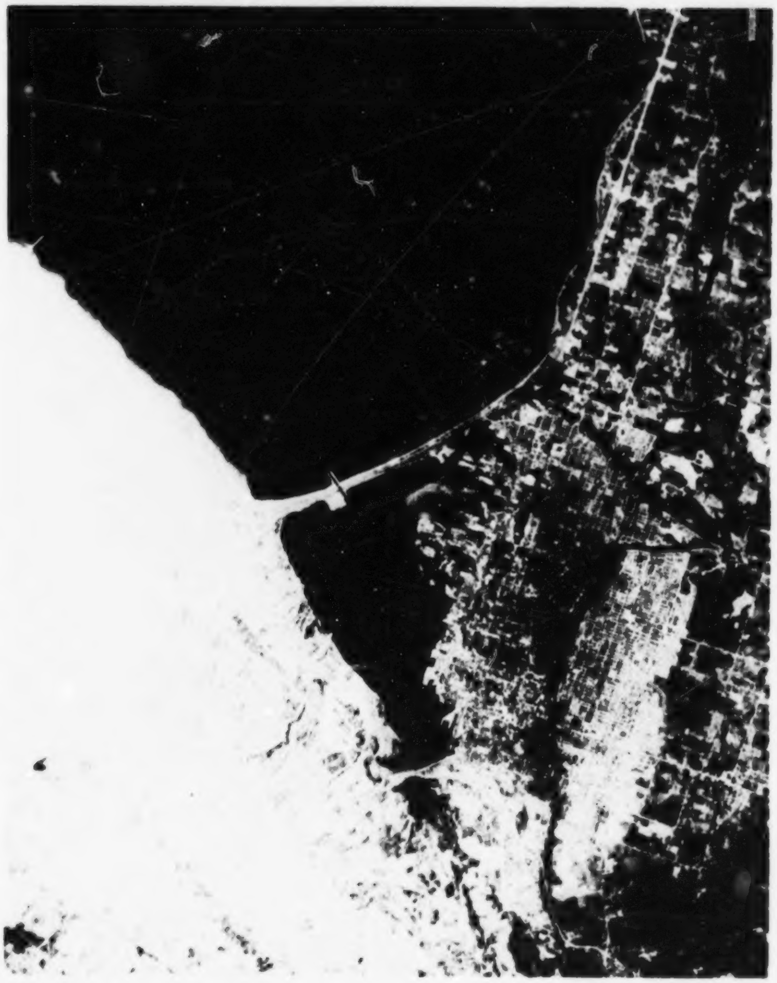


Figure 4.

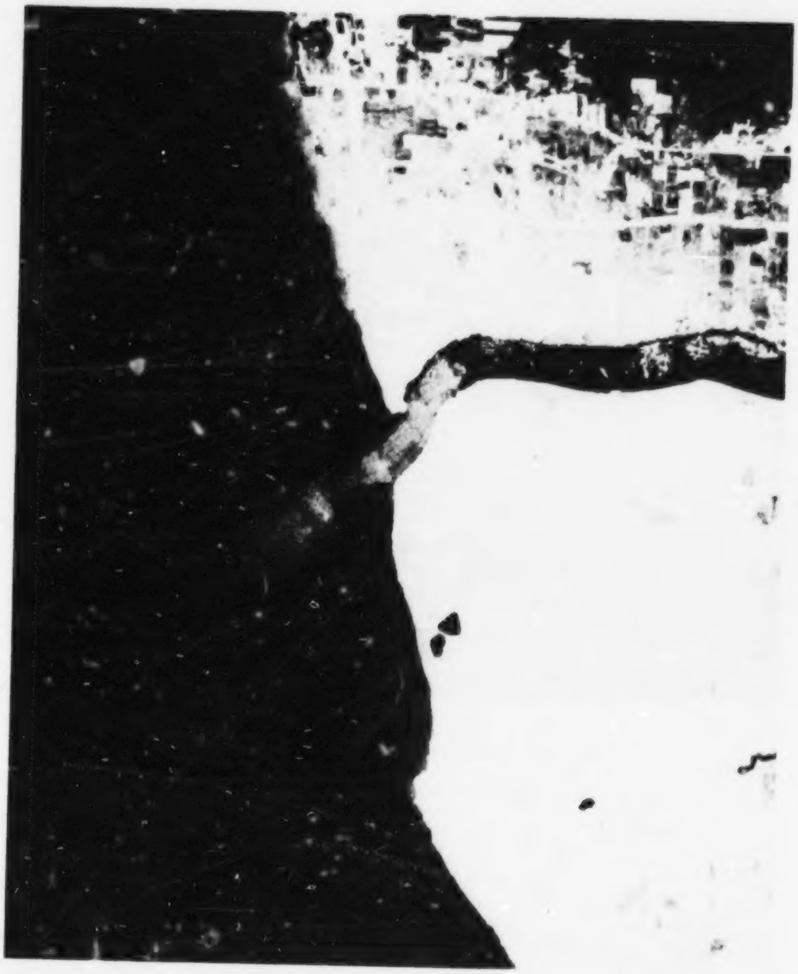


Figure 5.

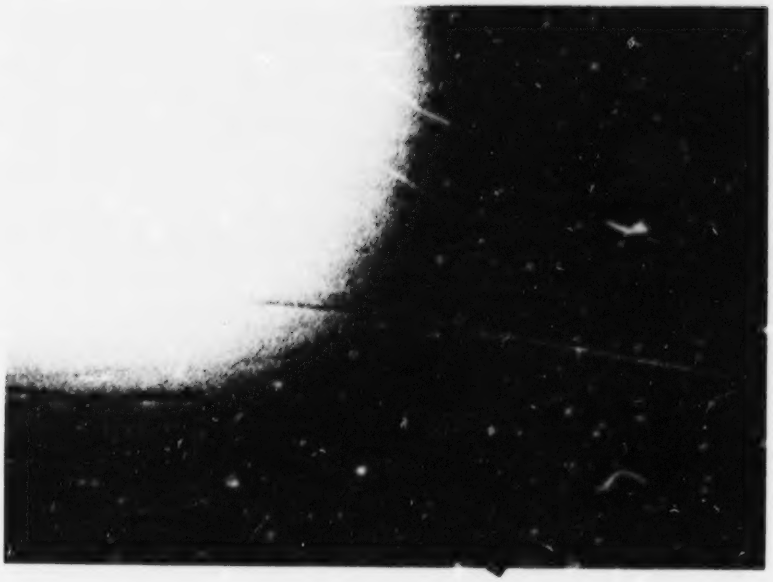


Figure 6.

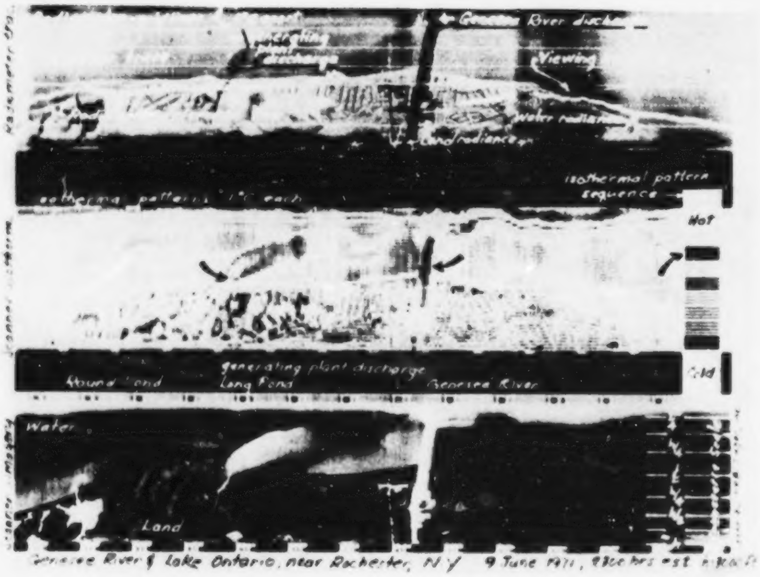

Genesee River discharge
generating plant discharge
Viewing
Water radiance
Land radiance
isothermal pattern sequence
isothermal patterns 1°C each
Hot
Cold
generating plant discharge
Round Pond
Long Pond
Genesee River
Water
Land
Genesee River & Lake Ontario, near Rochester, N.Y. 9 June 1971, 0300 hrs est.

Figure 7.

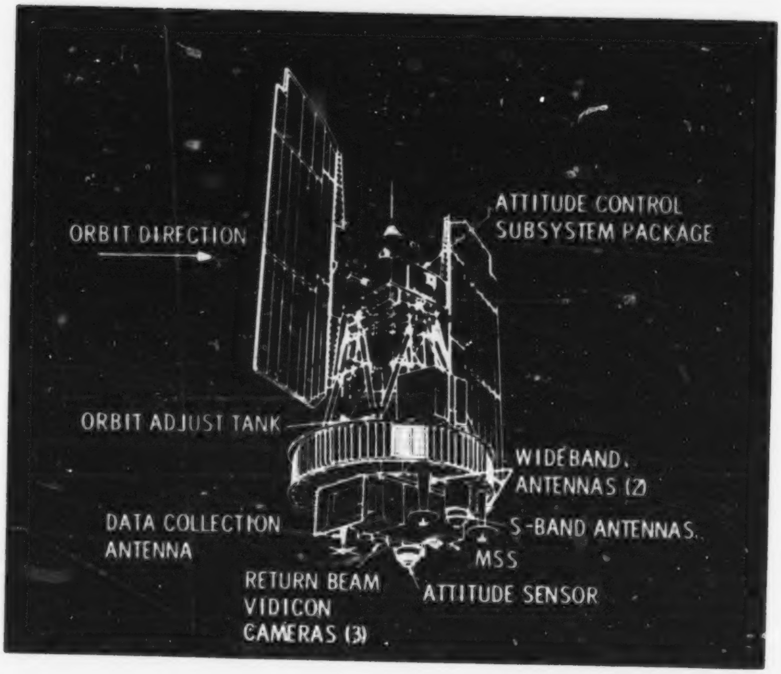

ORBIT DIRECTION
ATTITUDE CONTROL SUBSYSTEM PACKAGE
ORBIT ADJUST TANK
WIDEBAND ANTENNAS (2)
DATA COLLECTION ANTENNA
S-BAND ANTENNAS
MSS
RETURN BEAM VIDICON CAMERAS (3)
ATTITUDE SENSOR

Figure 8.

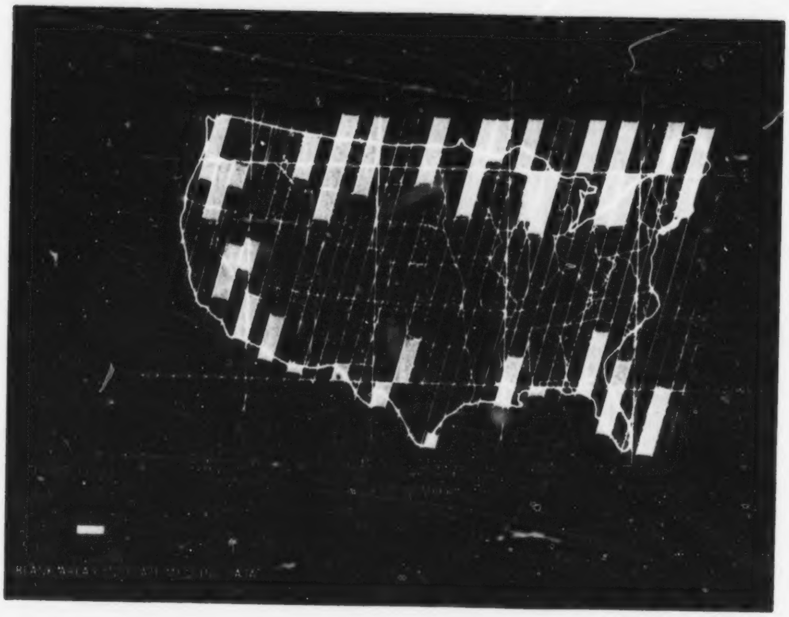


Figure 9.

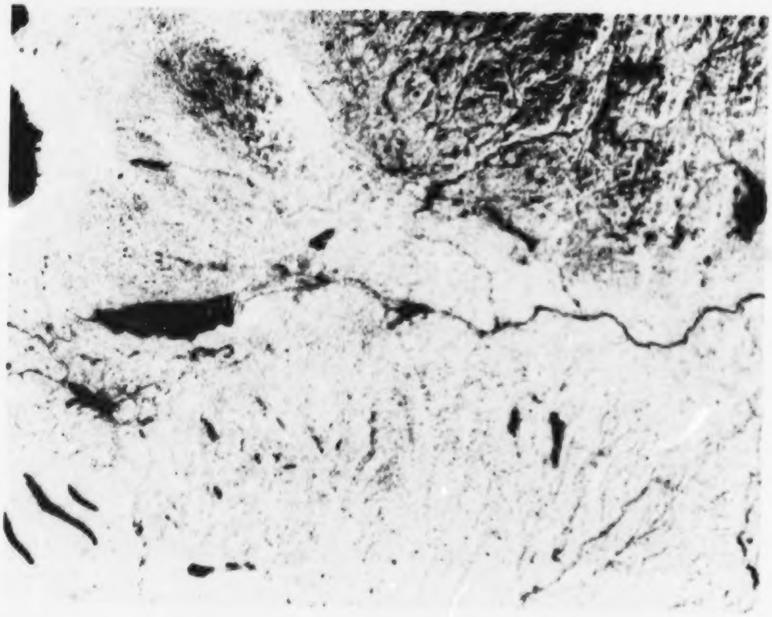


Figure 10.

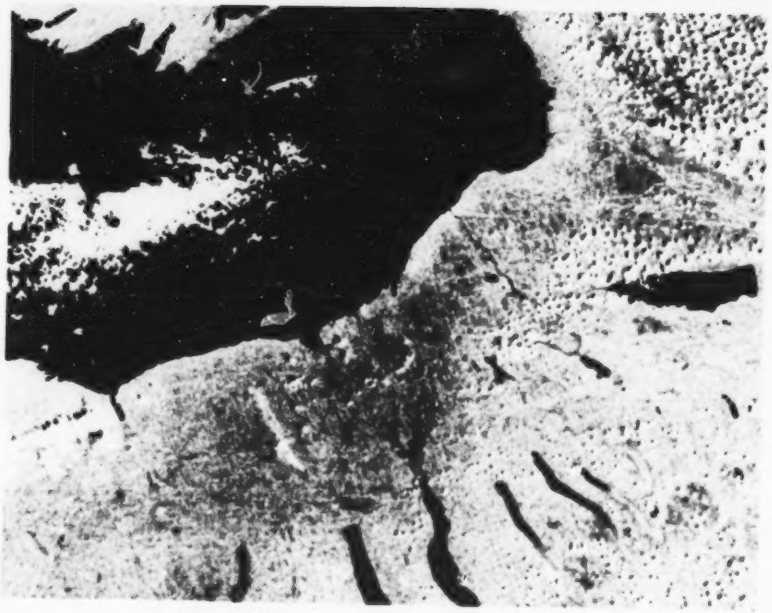


Figure 11.

Figure 12.

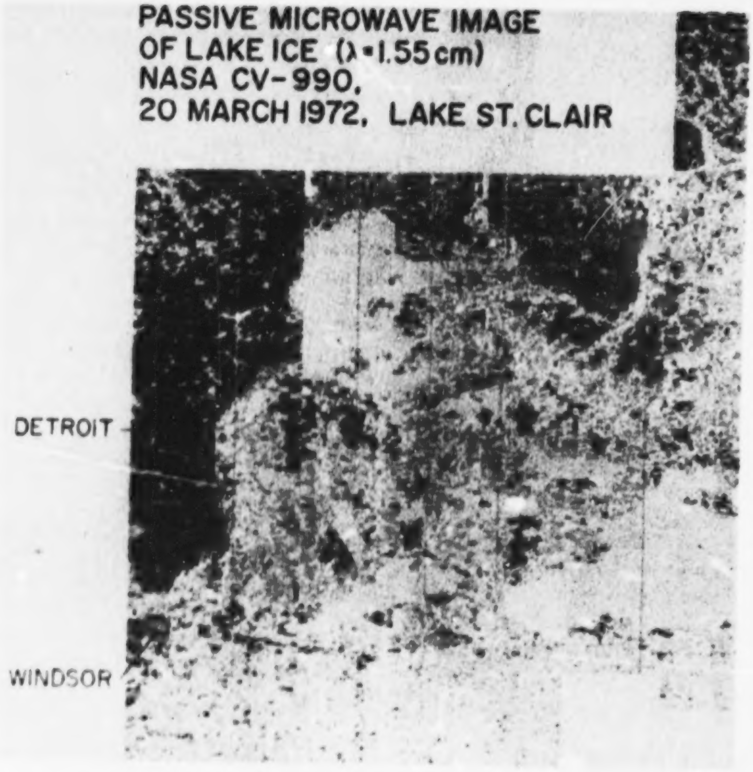
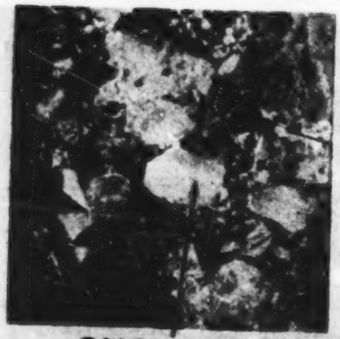
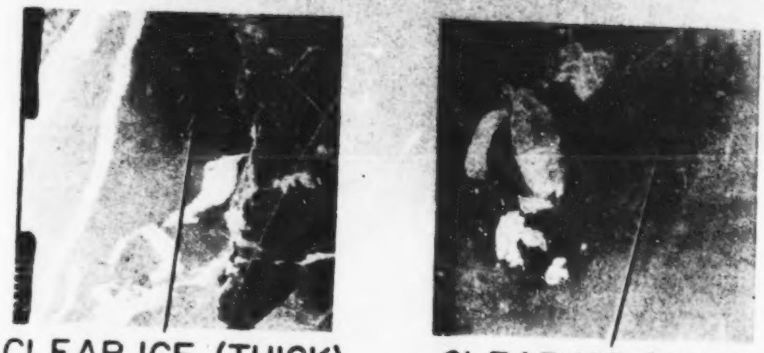

PASSIVE MICROWAVE IMAGE
OF LAKE ICE (λ=1.55cm)
NASA CV-990,
20 MARCH 1972, LAKE ST. CLAIR
DETROIT
WINDSOR

Figure 13.



SNOW ICE



CLEAR ICE (THICK) CLEAR ICE (THIN)

Figure 14.

A Program of Cooperative Water Resources Research and Training

John S. Gladwell, Water Research Scientist, Office of Water Resources Research, Department of Interior

ABSTRACT

The Office of Water Resources Research (OWRR) administers a program of water resources research as authorized by the Water Resources Research Act of 1964, as amended. Three purposes of the program are: (1) to develop through research new technology and more efficient methods for resolving local, state, and national water resource problems, (2) to train water scientists and engineers through their on-the-job participation in research work, and (3) to facilitate water research coordination and the application of research results.

To implement the program, OWRR provides annual fund allotments to a designated Institute at a university in each state and Puerto Rico, and will soon establish similar arrangements in Guam, the Virgin Islands, and the District of Columbia. Present funding levels are at $140,000 per annum. Substantial non-federal contributions are made. Funds are also available to universities for research on a dollar-for-dollar matching basis. Additional grants and contracts may be made with any qualified researcher for support of research work relating to the mission of the Department of the Interior.

In the past, OWRR has had no program of research related to the Great Lakes. However, primarily through individual programs of the eight States bordering those Lakes, a great deal of such research has been accomplished. In addition, the Water Resources Scientific Information Center has produced bibliographies of published materials dealing with each of the Lakes.

OWRR is now considering mechanisms by which multi-state multi-university programs of research on regional problems could be systematically pursued. Interest in such programs has been expressed by the state institute directors. The problems of the Great Lakes seem to present an excellent opportunity for testing this type of coordinated effort.

PROGRAM AUTHORIZATION

The program administered by OWRR is authorized by the Water Resources Research Act of 1964 (Public Law 88-379, July 17, 1964), as amended by Public Law 89-404, April 19, 1966, and Public Law 92-175, December 2, 1971.

PROGRAM OBJECTIVES

As stated in the preamble of the Water Resources Research Act of 1964: "In order to assist in assuring the Nation at all times of a supply of water sufficient in quantity and quality to meet the requirements of its expanding population, it is the purpose of the Congress, by this Act, to stimulate, sponsor, provide for, and supplement present programs for the conduct of research, investigations, experiments, and training of scientists in the fields of water and of resources which affect water." Consistent with this rather broad mandate, OWRR views its major program objectives to include: developing through research new technology and more efficient methods for resolving local, state, regional, and national water resource problems; training water scientists and engineers through their on-the-job participation in research work; and facilitating water research coordination and the application of research results through dissemination of information about ongoing and completed research.

NATURE OF THE PROGRAM

OWRR does not maintain its own laboratories or perform any in-house research. On an extramural basis, utilizing grants and contracts, it supports three basic research programs:

Allotments to State Institutes

Title 1, Section 100, of the Act provides for annual allotments of funds to a designated state university institute in each of the 50 states, Puerto Rico, the Virgin Islands, Guam, and the District of Columbia (the latter three were recently authorized but are yet to be funded). These grants are for assistance in establishing and carrying on the work of a competent and qualified water resources research institute. The function of these institutes is to conduct research, investigations, and experiments of either a basic or practical nature, or both, in relation to water resources; provide for the training of scientists through such activities; and interpret and disseminate information about research results to persons who can use such information.

In order to assure that the limited funds are spent on coherent programs that bear upon the major water-related problems of the states, the institutes use a variety of techniques for program planning. As recently amended, the Act further stipulates that ". . . . The annual programs submitted by the State institutes to the Secretary of the Interior for approval shall include assurance satisfactory to the Secretary that such programs were developed in close consultation and collaboration with leading water resources officials within the State to promote research, training, and other work meeting the needs of the State."

State institutes submit proposed programs to OWRR for review and approval pursuant to guidelines provided to the institutes. In many cases a state institute program will include projects to be carried out at two or more universities or colleges within the state. In this way additional expertise and capabilities are made available to the state institute. It is OWRR's policy to encourage such multi-university cooperative programs.

Matching Grants to State Institutes

Title I, Section 101, of the Act provides for grants to the state institutes to match, on a dollar-for-dollar basis, funds made available to the institutes by state or other non-federal sources to meet the necessary expenses of specific water resources research projects which could not otherwise be undertaken. The state institutes, and other universities and colleges in the state compete for these funds through the institutes by developing and submitting specific research proposals pursuant to OWRR guidelines provided to the institutes.

Final selection of matching grant research proposals is made by OWRR. However, advice and recommendations received from the state directors are given careful consideration in this selection process. Most institutes have a formal procedure, usually involving advisory committees, by which the most appropriate proposals are selected for forwarding to OWRR. Each proposal is accompanied by a relevancy statement prepared by the director and in many cases a ranking of the proposals in the order the institute believes is most appropriate to its research program. In the selection of projects by OWRR, regional distribution is considered, but the primary factors are the merit of the proposed research and development of a compatible research program when submissions from all institutes are weighed.

Additional Water Resources Research

Title II of the Act provides for grants, matching grants, contracts or other arrangements with educational institutions, private foundations, or other institutions; with private firms and individuals; and with local, state, and federal government agencies. Such grants are to enable recipients to undertake research which may be deemed desirable into any aspect of water problems not otherwise being studied and related to the mission of the Department of the Interior. Federal regulations require that under most circumstances universities and other institutions receiving Title II research grants shall share in the research costs. In particular, OWRR encourages and welcomes non-federal support for research projects where the research is directed towards finding solutions to urgent problems largely confined to a specific local area or state.

Title II research project proposals may be submitted directly to OWRR without going through a state institute. OWRR recommends, however, that those who are considering such submission make contact with the state institutes inasmuch as the directors can provide much helpful information regarding the Title II program. Title II guidelines are issued annually by OWRR, and these guidelines will normally include a listing of priority research subjects applicable to the Title II program.

Funding Authorizations and Appropriations for Research

The maximum amounts authorized by the Act for appropriation in FY 1973 and the amounts actually appropriated for each of the above three programs are as follows:

		Amount Authorized	Amount Appropriated
Title I (Section 100)	–	$13,125,000	$ 7,140,000
Title I (Section 101)	–	5,000,000	3,000,000
Title II	–	10,000,000	4,300,000
Total	–	$28,125,000	$14,440,000

The appropriation for the Section 100 Annual Allotment Program includes $140,000 for each of the 51 established state institutes, an increase of $40,000 above the amount each institute has received during previous years.

Although non-federal contributions to the annual allotment program are not a legal requirement, such contributions have amounted to about three-fourths of the federal input. The largest portion of the non-federal cost-sharing funds has consistently been provided through the two cooperative federal-state Title 1 programs.

Water Resources Scientific Information Center (WRSIC)

In accord with the responsibilities of coordination and technical information dissemination set forth in Sections 104 and 300 of the Act, OWRR, in cooperation with the Office of Science and Technology, established WRSIC. This Center assists in the general objectives of: (1) being responsive to the water resources scientific information needs of federal water resources organizations and others; (2) avoiding undesirable replication of research; and (3) improving communications and coordination of efforts among all those engaged in federally sponsored water-related research. WRSIC produces and disseminates various types of documents such as a biweekly abstract journal of research results and developments, an annual abstract catalog of ongoing research projects, state-of-the-art reviews, and topical bibliographies. It also operates a computer-aided program for retrieval of WRSIC information base material in response to specific inquiries. Three remote retrieval terminals with access to the main file of abstracts (which now exceed 45,000) are currently being field-tested. The terminals are located at the Title I Institute offices at North Carolina, New York, and Wisconsin.

ESTABLISHING RESEARCH PRIORITIES

In the establishment of 51 state institutes (soon to be expanded to 54) a great deal of initiative and responsibility has been given to the Directors in the development of their own research priorities and programs. The Act, however, is clear in that it expects that the institute programs will be developed "in close consultation and collaboration" with practitioners within the states. In general, OWRR imposes a minimum of administrative regulations and guidance. It is intended to be sufficient, however, to ensure effective fund use and that a cooperative effort exists between those who can visualize problems and those who have the capability to go about solving them, while at the same time imposing no undesirable or unnecessary constraints on research project investigators. Primarily, it is the responsibility of the institute (and usually that of its director) to ensure that a quality research effort is developed and carried out by the best qualified experts it can find. All Section 100 programs, nevertheless, are subject to OWRR review prior to funding.

The priorities for Section 101 matching grant research are influenced greatly by institutes' policies and priorities. All Section 101 proposals, whether originating from within the institute's university or from any other college or university within the state, must be submitted to OWRR by the state institutes.

For the Title II program, OWRR annually develops and disseminates a formal list of research subject priorities. These priorities are developed with advisory assistance and recommendations of other federal agencies and the Committee on Water Resources Research of FCST. Research priorities under this program vary only somewhat from year to year. For the FY 1974 program the priority list expands on the following areas:

(1) analysis of planning, managerial, financial, operating, and regulatory policies of water resources institutions.
(2) water resources policy and political institutions.
(3) hydrologic systems analysis.
(4) urban and metropolitan water resources problems.
(5) ecologic aspects and environmental consideration of water resources planning and management.
(6) evaluation of economic importance of various uses of water, cost allocation, cost sharing, pricing and repayment.
(7) analysis and evaluation of water resources projects.
(8) ground-water supply, management, and protection.
(9) protection and rehabilitation of estuarine resources.
(10) thermal loading problems.
(11) water demand considerations.

Although this priority list is developed specifically for the Title II program, it is clear that the institutes and individual investigators give it careful consideration in the development of the Title I programs, particularly the matching grant program.

GREAT LAKES RESEARCH

Although OWRR has had no program of Great Lakes research, it has in the past and continues to support a number of research projects identified as being so specifically oriented. Most of these have come through the Title I programs of the states bordering the Great Lakes inasmuch as problems of the Great Lakes have been identified by those institutes as being state problems.

Table 1: OWRR's Great Lakes Research Identified in 1972 *Water Resources Research Catalog*

Project Title	State	Amount in dollars (Federal)[1]				
		FY 1969	FY 1970	FY 1971	FY 1972	FY 1973
Hydrologic Models of the Great Lakes (B-0[illegible]-ILL)	Illinois	$	$	$	$	$27,700
A Case Study of the Implementation of the Michigan Bond Issue for Water Pollution Control (A-054-MICH)	Michigan				4,020	4,020
Systems Analysis of the Great Lakes (C-1602)	—					72,082
Source of Coliform Organisms in Northern Lake Michigan Waters (B-020-MICH)	"				1,408	
Zooplankton Biomass and Incipient Eutrophication in Lake Superior (A-022-MINN)	Minnesota		9,000	9,000	9,000	
Institutional Arrangements and Allied Law in Water and Related Land Resources Planning, Development and Management (C-1196 and C-2145)	New York					39,980 29,950
A Systems Analysis of the Western Basin of Lake Erie (B-017-OHIO, B-023-OHIO, and B-036-OHIO)	Ohio			30,000 97,090	49,920	
Interactions Between Microparticulates & Heterotrophic Microorganisms from Lake Erie Using Batch & Continuous Culture Techniques (A-021-OHIO)	"			5,880		5,600
Role of Fungi & Algae in Formation and Hy[illegible] of Lake Erie Sediments (A-02[illegible]-OHIO)	"			8,700	8,800	
Adpatation to Eutrophic Conditions by Lake Michigan Algae (A-041-WIS)	Wisconsin				4,629	

[1] *Years indicate duration of project and federal funds expended during each year. Additional non-federal funds have averaged nearly two-thirds of federal.*

Table 2: Department of the Interior Office of Water Resources Research—Total Research Program and by Selected States (in thousands of dollars)

State and Program	No. of Projects	Total Amount	FY 1972 Amount	FY 1971 Amount	FY 1970 Amount	FY 1969 Amount	FY 1968 Amount	FY 1967 Amount	FY 1966 Amount	FY 1965 Amount
Total Program:										
Annual Allotment	1720	$37,411	$5,100	$5,100	$5,100	$5,100	$5,100	$4,463	$4,463	$2,985
Matching Grant	665	18,750	3,000	3,000	3,000	3,000	3,000	2,000	1,500	250
Title II	216	13,800	4,300	3,500	2,000	2,000	2,000	—	—	—
Illinois:										
Annual Allotment	55	751	100	100	100	100	100	88	88	75
Matching Grant	30	907	120	145	180	217	103	83	59	—
Title II	4	162	46	20	96	—	—	—	—	—
Indiana:										
Annual Allotment	24	728	100	100	100	100	100	88	88	52
Matching Grant	16	462	101	97	125	58	—	81	—	—
Title II	4	359	325	34	—	—	—	—	—	—
Michigan:										
Annual Allotment	58	751	100	100	100	100	100	88	88	75
Matching Grant	8	182	64	—	60	—	36	22	—	—
Title II	9	668	83	216	209	—	160	—	—	—
Minnesota:										
Annual Allotment	23	728	100	100	100	100	100	88	88	52
Matching Grant	21	590	110	98	130	115	59	—	78	—
Title II	1	18	—	—	—	—	18	—	—	—
New York:										
Annual Allotment	40	751	100	100	100	100	100	88	88	75
Matching Grant	11	401	76	33	48	65	73	25	81	—
Title II	24	1,228	297	169	327	166	269	—	—	—
Ohio:										
Annual Allotment	27	751	100	100	100	100	100	88	88	75
Matching Grant	15	652	83	50	204	30	179	24	82	—
Title II	5	292	131	61	68	32	—	—	—	—
Pennsylvania:										
Annual Allotment	29	728	100	100	100	100	100	88	88	52
Matching Grant	19	428	120	93	96	30	40	29	20	—
Title II	13	877	186	267	82	84	258	—	—	—
Wisconsin:										
Annual Allotment	14	728	100	100	100	100	100	88	88	52
Matching Grant	21	766	84	104	94	158	72	137	117	—
Title II	2	119	39	—	—	—	80	—	—	—

Table I identifies those projects active during FY 1972 which specifically listed Great Lakes (or any one of the Great Lakes) as identifiers. It should be noted that the procedure used for selecting these projects required such an identifier and that a great deal of research is being undertaken which, though having transferability to Great Lakes problems, was not specifically identified as such.

OWRR believes it has created and nurtured broadly competent centers of excellence for water resources research in each state. It is now considering the mechanisms by which these competences can be put together into multi-state multi-university teams for effective cooperative efforts. The problems of the Great Lakes offer an excellent opportunity for such a regional grouping. Such a team, with effective consultation and collaboration with leading water officials at the local, state, regional, and national levels, would proceed to identify the dimensions of the serious problems requiring urgent attention. The systematic analysis of research requirements would be followed by a planned and coordinated delegation of research responsibilities.

The concept for such a mechanism has been proposed to several regional groups. The response by the directors of the state institutes to date has been most enthusiastic. The potential for mounting research programs in the Great Lakes states can be seen in Table 2, where the OWRR research fundings are itemized by program. Whereas the Section 100 funds are equal for each state, these eight states (14% of the 51) accounted for 21% of the matching grant projects (23% of the funds), and 29% of the Title II projects (27% of the funds). Clearly these states have a recognized capability to do quality water resources research. OWRR believes that a positive program of collaboration and cooperation with other research groups (federal and non-federal) is the best way to proceed.

A review of WRSIC's computerized abstracts for OWRR-funded completed projects listing the same identifiers indicated that 58 such abstracts were on file. Of the 58 abstracts, a breakdown by area is as follows:

Great Lakes	25
Lake Erie	18
Lake Huron	6
Lake Michigan	11
Lake Ontario	5
Lake Superior	17
Total	82*

A summary of the 58 abstracts by state from which the abstracts were reported is as follows:

Illinois	5
Michigan	7
Minnesota	8

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*Some reports index two or more Lakes, so that the total by Lakes is greater than the number of abstracts.

New York	6
Ohio	18
Wisconsin	14
Total	58

As noted previously in Section IV-E, OWRR produces through WRSIC topical bibliographies of research results from its computerized abstracts. These publications are available for purchase generally through NTIS. They are prepared either by special request from an outside agency or by OWRR decision. During June-August of 1972, WRSIC produced such bibliographies for the Great Lakes—one for each of the five. They were selected from the total file of (at that time) more than 42,000 abstracts. The number of abstracts found to be identified with each Lake were as follows:

Lake Erie	221
Lake Huron	59
Lake Michigan	242
Lake Ontario	131
Lake Superior	82

CONCLUSIONS AND RECOMMENDATIONS

Although OWRR has not in the past identified the Great Lakes as an area requiring a specific priority research program, it has the flexibility to do so should sufficient evidence be produced to justify such action. OWRR is now considering such a move. We would be most interested in participating with other research groups in the development and conduct of a program of such research and have no doubt that the same can be said of our institute directors. In fact, we recommend that such a program development use the capabilities and facilities of our state institutes. We feel strongly that the universities involved in our programs have shown themselves to be willing and competent to do research that has applicability to major problems of our water resources.

It is our feeling that Great Lakes research should be developed as a program, and not be allowed to drift along as a series of vaguely related projects. Because of its international character, the International Joint Commission could serve as the host agency for such an action. The Office of Water Resource Research and its institutes stand ready to cooperate in such an endeavor.

The Environmental Protection Agency's Role in Great Lakes Research

Dr. John L. Buckley, Deputy Director, Office of Research, Environmental Protection Agency
Dr. Tudor T. Davies, Director of Grosse Ile Laboratory, Office of Research and Monitoring, Environmental Protection Agency

In the pre-Environmental Protection Agency (EPA) days, there was a long history of changing agencies and of fragmentation of the federal pollution control programs among many agencies. This made it impossible to integrate the planning, research and standard-setting that is necessary to deal with pollution.

The EPA was created to fulfill the need for a single agency responsible for the development of an integrated research, standard-setting, and assistance program. The mission of the agency was directed to those functions essential to setting standards for pollution control. Because it is primarily a regulatory agency, the standards that the agency functions provide must have a sound scientific basis. Too, it must have a capacity to evaluate the success of the standards through a monitoring program. To ensure this, the agency must have a strong research capacity which covers all the major classes of pollutants and also the two major transporting media: air and water. Obviously, EPA does not have the resources or the mandate to do all the research necessary, but it must attempt to assure that the necessary research is done. EPA is a relatively small agency. This conference is of special significance for our agency because we have a special responsibility to see that the necessary research is conducted on the Great Lakes so that we can understand the water system as a basis for a comprehensive management system.

Through our deliberations we hope that we can evaluate the federal effort on the Great Lakes and perhaps suggest within our own agency and to other agencies present the research efforts that need to be conducted on the Great Lakes.

The agency is new, and much has happened in the short period of our existence. Ten strong regional organizations have been established throughout the country. Each region has an administrator with a complete staff of local experts in the program areas (such as air and water) and in law enforcement. These regional offices serve and in turn are served as the principal contact with the states. The states have the primary responsibility to prevent, reduce and eliminate water pollution.

The EPA regional offices work closely with state agencies in programs which include surveillance of water quality, enforcement and the establishment of water quality standards and the formulation and enforcement of regulations; basin planning for meeting water quality standards; grants for construction of treatment plants; and contingency planning for controls of spills of oil and hazardous materials.

EPA is also a primary review agency of environmental impact statements prepared for federal projects under the National Environmental Protection Act (NEPA) of 1969.

Up to the passage of the Federal Water Pollution Control Act (FWPCA) Amendments of 1972, EPA has used three enforcement tools to expedite clean-up of the nation's waters. These are:

(1) enforcement conferences
(2) water quality standards with 180-day notices
(3) Refuse Act of 1899

Enforcement conferences were called at the request of the states and required the state and federal agencies responsible for pollution control to meet, analyze the problem in a specific area, hear testimony from waste dischargers, establish control requirements, and set dates for compliance. Conferences have been held for Lake Michigan, Lake Superior, and Lake Erie.

The FWPCA of 1965 and subsequent legislation required the states to establish water quality standards for interstate waters which designated the levels of water quality to be maintained for designated uses along specified reaches or areas of water bodies and an implementation program to meet the standards. After approval by EPA, violations of the standards were enforced by a notice and hearing procedure followed by court action if necessary.

EPA has also used the 1899 Rivers and Harbor Act which, under a broad interpretation by the courts, limits discharges of any foreign substance to navigable waterways. This has been especially effective in controlling accidental spills of oil and hazardous materials. Violation cases are sent to the U.S. Attorneys for prosecution.

In 1970 Executive Order 11574 created a program under the 1899 Refuse Act whereby industrial dischargers apply to the Corps of Engineers for a permit to discharge to navigable waters. Under this program the EPA and states review the information in the application and establish conditions to the permit which could include further waste treatment. Because of a Federal District Court decision in the case of Kalur *v* Resor, no permits may be issued at this time.

The FWPCA Amendments of 1972, however, established a new system of permits for dischargers. The law authorizes EPA and the states which have an adequate permit program to issue permits. The new law also extends federal control to all U.S. waters and authorizes the federal government to seek immediate court injunctions in cases of severe threats to health or livelihood.

The research and development programs of predecessor agencies have been reorganized within EPA into four National Environmental Research Centers (NERCs) which have associated laboratories. Each of these NERCs has a distinct but non-exclusive role:

Cincinnati, Ohio, for pollution control technology
Research Triangle Park, North Carolina, for health effects
Corvallis, Oregon, for ecologic effects
Las Vegas, Nevada, for environmental monitoring

These NERC centers provide much of the data for standard-setting and enforcement. They evaluate what is being introduced into the environment and its impact on ecologic stability, on human health and other factors important to human life. All the work in research and technology done in the agency is in anticipation of its use in problem solving.

The major aims of the agency's research effort at this time include expansion and improvement of environmental monitoring and surveillance to provide baselines of environmental quality; better understanding of long-term exposure to contaminants, of sub-acute or delayed effects on humans and other organisms, and of the combined and synergistic actions of chemical, biological, and physical stresses; acceleration of applied research into the control of pollutants, recycling of wastes, and development of non-polluting production processes; improved assessments of trends of technical and social change and potential first-, second-, and even third-order effects on environmental quality; increased understanding of the transport of pollutants through the environment and their passage through air, water, land and biological systems; their ability to cross the various interfaces; and the various changes that can make them innocuous at one point and hazardous at another.

Many of the agency's national research efforts are relevant to the Great Lakes and, although we have distinct Great Lakes-oriented programs which are described in detail at this conference, much of the other research has direct application to the Lakes.

Two distinct pieces of legislation direct our Great Lakes-focused programs. The first is the new Federal Water Pollution Control Act Amendment, which states unequivocally that: "The Administrator shall conduct research and technical development work, and make studies, with respect to the quality of the waters of the Great Lakes, including an analysis of the present and projected future water quality of the Great Lakes under varying conditions of waste treatment and disposal, and evaluation of municipal, industrial, and vessel waste treatment and disposal practices with respect to such waters, and a study of alternate means of solving pollution problems (including additional waste treatment measures) with respect to such waters."

The program element, Fate of Pollutants in Large Lakes, is specifically designed to answer this commitment. This program element is directed at this time almost entirely into the agency's contribution to the International Field Year for the Great Lakes (IFYGL) program, and we see excellent prospects of very significant accomplishments in understanding a major lake system from this international effort.

The Nixon-Trudeau Agreement on Great Lakes Water Quality has also produced a significant effort by the agency directed to the Great Lakes. In this agreement, the International Joint Commission is given the major responsibility for implementing the agreement, and the agency's support for the Commission can be seen from the prime position held by Francis Mayo, the Regional Administrator of Region V, as the U.S. Co-Chairman of the Water Quality Board, and Dr. Stanley Greenfield, the Assistant Administrator for Research and Monitoring, as the U.S. Co-Chairman of the Research Advisory Board. These are the two major advisory boards created by the Agreement.

Also, beyond a strictly advisory program, a Great Lakes initiative program is being developed jointly between Region V and the research arm of EPA. This includes a program of distinctly task-oriented research in the Great Lakes, an Upper Great Lakes Reference Study, a demonstration grant program under Section 108 of the new FWPCA Amendments, and special enforcement studies. The details and the budget for this program are still under development at this time.

Three parts of the processes and effects research program, namely health effects, ecological effects, and transport processes through the environment, have a broad national scope. Though they may be peripheral to the Great Lakes geographic region, they have a distinct impact on the Agency's approach to water quality management in the Great Lakes.

Most of the ecologic effects and transport processes research is coordinated by the NERC Director at Corvallis, Dr. A. F. Bartsch, and we think this program has made significant contributions to research. As an example, the aquatic ecology research program has contributed very significantly to the so-called new Blue Book on water quality criteria prepared by the NAS-NAE.

The series of EPA programs called "Fate of Pollutants in Fresh, Surface, Ground and Lake Waters" has direct impact on the Lakes. Considerable effort has been made in the realm of eutrophication studies, and a recent venture is an assessment of the state of eutrophication of a large number of lakes through the United States.

Our National Environmental Research Centers are responsible for both in-house and extramural research, with our efforts being more or less evenly divided.

Currently in 1973, we are spending $3.739 million on aquatic ecology research, $1.286 million on the fate of pollutants in fresh water research, and $1.4 million on eutrophication and lake restoration research.

Other EPA very practically oriented research programs in technology research are industrial and municipal waste treatment impact on the Great Lakes, but I think that these are beyond the scope of this presentation. If we can help anyone become acquainted with this research, we shall be delighted to do so.

This paper has provided an overview of EPA's research as it applies to the Great Lakes. More detail of some of the specific research programs are discussed in the paper on Great Lakes studies by Tudor Davies, and other activities, such as those at Duluth and at Ely, are described in Nobert Jaworski's paper.

We look forward to increased cooperation with all of you here in planning and carrying out the research needed to support good management of the Great Lakes.

In closing, I should like to call attention to the U.S.-U.S.S.R. Agreement on Environmental Protection signed by President Nixon and Chairman Podgorny on May 23, 1972 in Moscow. Among the several areas specified for cooperation is water pollution. Within this subject area, cooperative and comparative studies of Lake Baikal and the Great Lakes were singled out. We anticipate a fruitful exchange, involving a visit of a U.S. group to Lake Baikal in the summer of 1973 and, hopefully, a return visit by a Soviet delegation in early fall of 1973.

Great Lakes Programs of the Grosse Ile Laboratory

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ABSTRACT

There are two major programs within the U.S. Environmental Protection Agency (EPA) that are directly concerned with research on the Great Lakes, both of which are directed by the Grosse Ile Laboratory. These programs respond directly to the authority given the Agency by the Water Pollution Control Act and its amendments, and by the Great Lakes Water Quality Agreement. The laboratory is only in its second year of operation. The staff plans and works very closely with extramural research organizations, largely universities, that carry out the research under grants and contracts. The first program is aimed largely at the development of general predictive models of large lakes which will include chemical biological and physical sub-models. The data requirements for formulating these models will be derived from the biological and chemical investigations of the status of Lake Ontario during the IFYGL. The biologic studies are largely contracted to university investigators while the material balance investigations are in-house studies conducted at the Rochester Laboratory of EPA. After completion of the field year an assessment of how these Ontario modeling effects can be adapted to the other Lakes will be made. The models will be used to evaluate present water quality standards and aid in the formulation of new guidelines for the management of lakes.

The other research efforts in the large lakes and the Great Lakes program are very practically oriented towards solving specific problems and developing specific guidelines and standards for management of the Lakes. Four specific research needs are addressed in the planned research program.

The first is eutrophication and nutrient control in the Great Lakes. This involves both a comprehension of the nutrient requirements for the growth of problem algae and a systematic evaluation of the effectiveness of the initiated nutrient control program.

The second is the development of predictive management models for the transport of nutrients, hazardous material, and other pollutants and models of biological and chemical processes. The third is an evaluation of the ecologic impact of thermal pollution of the Lakes. The final need is to determine the impact of dredging and spoil disposal in the Lakes and to develop criteria for control of this impact.

* * *

Public laws over a span of ten years have addressed the various agency secretaries and administrators in quite specific terms, instructing the Water Pollution Administration, later the Environmental Protection Agency, to conduct research on the quality of the waters of the Great Lakes. In response to these directives, the EPA Great Lakes Research Facility was planned to be located on the campus of the University of Michigan. Lack of funds delayed the construction of this facility, and to expedite the implementation of the research program some Lakefront land and buildings were acquired from the Navy at Grosse Ile, Michigan. These facilities are being progressively renovated. They are currently shared by the Lake Huron Basin Regional Laboratory of Region V, which has its headquarters in Chicago.

The specific section of the Federal Water Pollution Control Act Amendments of 1972 referring to the EPA states that "The Administrator shall conduct research and technical development work, and make studies, with respect to the quality of the waters of the Great Lakes, including an analysis of the present and projected future water quality of the Great Lakes under varying conditions of waste treatment and disposal, an evaluation of municipal, industrial, and vessel waste treatment and disposal practices with respect to such waters, and a study of alternate means of solving water pollution problems (including additional waste treatment measures) with respect to such waters."

In the period since the directive was initially given from Congress a great deal of research and research planning have gone forward through the various predecessor administrations, states, other federal agencies, and the Canadian research effort. But still, the urgency to acquire a better knowledge of the Great Lakes can be realized from the following tabulation of enforcement and international activities on the various Lakes:

Lake	Activity	Problem Area
Michigan	Enforcement Action	Thermal Pollution
Michigan	Enforcement Action	Overall Pollution*
Erie	Enforcement	Overall Pollution
Superior	Enforcement Action	Iron Mining
Ontario	IFYGL	Overall Pollution
Erie, Detroit and Buffalo Rivers	IJC	Overall Pollution
Huron	IJC Reference Study	Proposed Studies FY 1973
Superior	IJC Reference Study	Proposed Studies FY 1973

Eutrophication is one of the main problem areas delineated.

The data being used to formulate enforcement actions, IJC reports, and recommendations to the governments on the Great Lakes is limited, and there is an obvious need for a systematic approach to providing the basic infor-

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*Overall pollution includes all types of wastes with major effects being discharged from municipal and industrial sources.

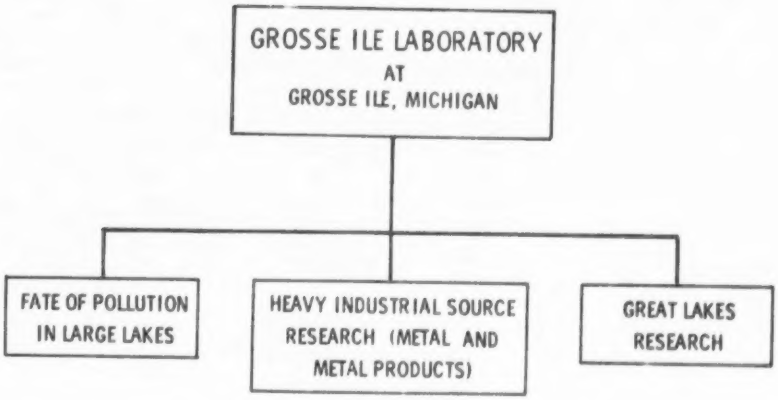

GROSSE ILE LABORATORY
AT
GROSSE ILE, MICHIGAN
FATE OF POLLUTION IN LARGE LAKES
HEAVY INDUSTRIAL SOURCE RESEARCH (METAL AND METAL PRODUCTS)
GREAT LAKES RESEARCH

Figure 1. Organizational structure Grosse Ile Laboratory NERC-Corvallis

mation needed to make decisions on the large-lake pollution problems. The research program at the Grosse Ile Laboratory has been developed in response to the expressed research needs of the Office of Research and Monitoring of the EPA (Figure 1). These research needs are formulated from "need statements" generated by the regional offices of EPA which distill the most pressing research needs as assessed by them and the state and local environmental control offices. The Grosse Ile Laboratory staff has made use of the federal, state and academic research community in its research planning. We would like to express our thanks specifically to a small band of people who have given freely of their time and experience.

The following major water quality management problems were identified among the research needs of the Great Lakes:

(1) nutrient overenrichment resulting in excessive nuisance aquatic growths
(2) increasing build-up of dissolved solids
(3) bacterial contamination of the shorelines near large municipal areas
(4) chemical contamination from industrial waste discharges and agriculture runoffs
(5) oxygen depletion of the hypolimnion of certain regions of the Great Lakes with concomitant undesirable changes in species composition, e.g., the removal of large areas from fish production
(6) changes in the aquatic environment by waste heat discharges
(7) changes in sediments by entry of allochthonous material into the Lakes and disruption of the autochthonus matter within the Lakes such as by dredging.

Three categories of research needed to cope with these problems were also identified: (1) the theory of large lake processes including the assessment of the impact of pollution on the environment, (2) control technology needed at the source of pollution or to recover the environment, and (3) management and institutional arrangements needed to implement the control measures.

The first category is being addressed by the research program developed under the heading, "Fate of Pollutants in Large Lakes," which has the following objectives:

(1) development of methodology to measure, describe, and predict the time-space distribution of pollutants and resulting effects on the water quality as influenced by physical, chemical and biological factors

(2) development of methodology for interfacing water quality predictive and management models

(3) monitoring of long-term changes in biota and water quality while examining relationships to changes in environment

The emphasis of the Large Lakes Research Program focuses in four areas:

(1) *Nutrient Control Requirements.* An attempt will be made to refine and define where necessary the control requirements to reverse the eutrophication problems in the Great Lakes.

(2) *Waste Heat Discharge Control Requirements.* This effort will be jointly conducted among Region V Thermal Pollution Program, the National Water Quality Laboratory, and the Grosse Ile Laboratory. Field studies relating to entrainment and associated efforts due to existing facilities are being studied.

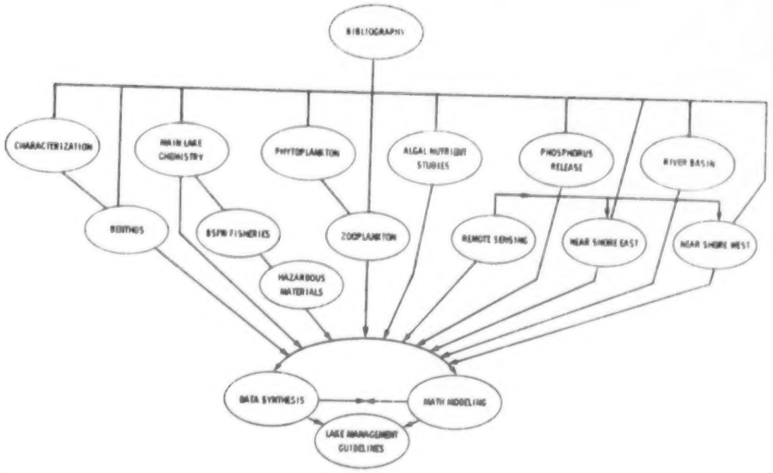
(3) *Dredging Control Needs.* As part of the Ocean Dumping Program initiated by CEQ, field activities related to effect of dredging disposal will be conducted through extramural activities.

(4) *Hazardous Material Flow.* In recent years high concentrations of mercury, DDT, and PCB's have been detected in fishes of the Great Lakes. Efforts were initiated by EPA to quantify the sources of pesticides in Lake Michigan. This effort will be expanded to include other hazardous material in all the Great Lakes.

This program was initiated at a very significant time since the International Field Year for the Great Lakes (IFYGL) was in its final planning stages. The IFYGL, which is the major North American (U.S.-Canada) program of the International Hydrological Decade, has been designed as a very comprehensive analysis of Lake Ontario. One of its major goals, as defined by the International Steering Committee, is "to advance the state of knowledge of large fresh water lake systems as a basis for the resolution of water quality problems, particularly those faced jointly by the United States and Canada on the Great Lakes."

There are six primary programs in IFYGL, (1) lake meterology, (2) energy balance, (3) water movement, (4) terrestrial water balance, (5) boundary layer, and (6) chemical and biological studies which, although separate in many aspects of conception and operation, are unique in the scope of the scientific investigation, the application of new technologies to the Great Lakes, and in the degree of coordination among government agencies and the university community in both countries.

The EPA assumed the lead agency role for the chemistry-biology program, and the Grosse Ile Laboratory staff were given planning responsibility for the program. However, though only directly concerned with the chemistry-biology program, the EPA will benefit from the interdisciplinary analysis of all the IFYGL information. Further advantages that will be derived from the IFYGL,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REMOTE SENSING
NEAR SHORE EAST
NEAR SHORE WEST
HAZARDOUS MATERIALS
DATA SYNTHESIS
MATH MODELING
LAKE MANAGEMENT GUIDELINES

Figure 2. IFGYL U.S.-Canadian Chemistry-Biology Program

and I hope in some measure from the present conference, are development of the capacity for extensive interdisciplinary and interorganizational studies and a developed capacity for strengthening new institutional arrangements for improved management of the Great Lakes System.

The Environmental Protection Agency, in conjunction with the National Science Foundation, Bureau of Sport Fisheries, and New York Department of Environmental Conservation, has assumed responsibility for developing and funding the U.S. Chemistry and Biology Program.

A scientific program which began in April 1972 was developed in three areas (Figure 2):

(1) Material balance studies. This involves the evaluation of the relative importance of pollution sources and the identification of sites where control measures could be effective

(2) Research on the theory of large lake processes, including an assessment of current pollution stresses. This embraces establishing the current ecological status and conducting scientific studies of processes, rates, and mechanisms of the lake as required to determine abatement and management needs and to monitor the effectiveness of such efforts

(3) Mathematical modeling and data synthesization. This aspect includes the development of predictive tools (mathematical models) for making management decisions.

There are two major parts to the EPA effort. One part, which includes most of the analyses for the materials balance study, is conducted as an in-house effort through the Region II Rochester, New York, Laboratory. This is an effort involving at least $250,000 and nine man-years for each year of the IFYGL operation. The second part, which includes most of the biologic parts of the program, sponsored by EPA, is conducted extramurally under a grant and contract program. The staff at Grosse Ile will take a progressively larger role in the research effort in the analysis phase of the field year. The total cost of the grant and contract program in 1972 for field-year-related activities was $650,000, and approximately the same funding level is expected for 1973.

Other grants and contracts in the Large Lakes Program are for the evaluation of the chemical reactivity of dredged spoil, an evaluation of the effect of once-through-cooling at the Monroe, Michigan, power plant, and an evaluation of the nutrient control of algae growth in Ontario, Erie and Michigan. The total budget for the Large Lakes Program in 1972 is $1,150,000.

The U S-Canada Agreement on Great Lakes Water Quality, which was signed in April 1972, resulted in EPA developing a Great Lakes Initiative Program, the six phases of which are outlined below. The planned budget for this research program is $903,000. The sixth part of the initiative is the development of the research program at Grosse Ile to address specific problems in Great Lakes Water Quality. The Initiative Program is as follows:

(1) ten selected field enforcement studies
(2) under Federal Pollution Control Act Amendments, Section 108a, demonstration grants of new technologies or regional studies, partially financed by local governmental institutions.
(3) agricultural run-off study
(4) Upper Great Lakes Reference Study, Lakes Huron and Superior.
(5) support of the IJC Research Advisory Board
(6) research program at the Grosse Ile Laboratory (Great Lakes research)

The planned research program is further divided into three basic phases:

(1) eutrophication and nutrient control. This is a program to develop a comprehension of the nutrient requirements for the growth of problem algae and systematic evaluation of the effectiveness of the instituted nutrient control programs.
(2) development of predictive models for the transport of nutrients, hazardous materials, and other pollutants, and the development of models of biological and chemical processes in the Great Lakes
(3) development of guidelines for controlling the ecologic impact of thermal pollution. We consider that the specific water quality objectives of the U.S.-Canada Agreement can be met only by effective management of the Lakes by use of predictive transport and process models.

The Grosse Ile Laboratory is further involved in the implementation of the U.S.-Canada Agreement in its role as Secretariat to the IJC Research Advisory Board on the Great Lakes. The U.S. Co-chairman of this board is Dr. Stanley M. Greenfield, Assistant Administrator for Research and Monitoring.

The final activity in this program is the coordination of research and monitoring activities with EPA regional programs.

The relationship of the activities at the Grosse Ile Laboratory and other EPA research facilities to the management needs of the Great Lakes are summarized in Table 1. The Environmental Protection Agency is regulatory in its charge. Therefore the activities of the research and monitoring program are directed to management goals. These activities are both oriented toward the environment and health.

Table 1: Mechanism for providing management tools in the Great Lakes

RESEARCH NEED	GIL	PNWL	NWQL	MANAGEMENT ACHIEVEMENT	REGIONAL RESPONSE
EUTROPHICATION	NUTR. ALGAL STUDIES	ALGAL ASSAYS		GUIDELINES	IJC EFFLUENT STD PERMIT PROGRAM
TOXIC - INORGANIC	PATHWAY STUDIES		EFFECTS OF SPECIFIC TOXICANTS		
TOXIC - ORGANIC	PATHWAY STUDIES			GUIDELINES	PERMIT PROGRAM
PATHOGEN	PREVALENCE			GUIDELINES	PERMIT PROGRAM
THERMAL	LAKE EFFECT	DESIGN	ORGANISM STRESS	GUIDELINES	PERMIT PROGRAM
DREDGING	CHEM. REACTION, BIO EFFECTS		TOXICITY OF SPECIFIC COMPOUNDS STRESS STUDIES	GUIDELINES	PERMIT PROGRAM
FISHERIES	COOPERATED WORK W/BSFW			GUIDELINES	
SEDIMENT EROSION	W/CORP. REEFS				
ICE	EXTENDED SHIPPING				
RECREATION	LAKE USE STUDIES				

GIL — GROSSE ILE LABORATORY
PNWL — PACIFIC NORTHWEST ENVIRONMENTAL RESEARCH LABORATORY
NWQL — NATIONAL WATER QUALITY LABORATORY

Activities of the Regional Offices

Carlyle Pemberton, Jr., Great Lakes Coordinator,
Region V, Environmental Protection Agency
Kenneth Walker, Director, Rochester Office,
Region II, Environmental Protection Agency

ABSTRACT

Three EPA Regional Offices carry out the Agency programs in the Great Lakes Basin. Region II (New York City) is responsible for that portion of the Basin in the state of New York, Region III (Philadelphia) is responsible for Pennsylvania, and Region V (Chicago) for the remainder of the Basin.

All of the Regions carry out policies and implement programs which have national application. National goals stated on the 1972 Amendments to the Federal Water Pollution Control Act are: eliminate the discharge of pollutants into navigable waters by 1985, and attain an interim goal by July 1, 1983, of water quality which provides for the protection of fish and wildlife and for recreation. National policies are established in the legislation to prohibit the discharge of toxic pollutants in toxic amounts; provide Federal financial assistance to construct publicly owned waste treatment works; develop and implement areawide waste treatment management plans; and undertake a major research and demonstration effort to eliminate the discharge of pollutants.

The Regions also carry out, individually or cooperatively, program activities which have specific application to one or more of the Great Lakes. Region II has responsibility for the U.S. chemical and biological sampling program for the International Field Year on the Great Lakes. Region V has lead responsibility for EPA participation with the Great Lakes Basin Commission, the International Joint Commission, and the Demonstration Program for Extension of the Navigation Season on the Great Lakes and St. Lawrence Seaway.

* * *

INTRODUCTION

Regions of the Environmental Protection Agency (EPA) are organized along state boundaries. In the Great Lakes Basin three Regional Offices have responsibility for carrying out Agency programs. Region II, with the Regional Office in New York City, includes that portion of the Basin in the state of

New York, that is, Lake Ontario and the eastern tip of Lake Erie. Region III with the Regional Office in Philadelphia, has that part of the Basin in Pennsylvania, or about 50 miles of Lake Erie shoreline. Region V, with the Regional Office in Chicago, has the remainder of the Basin, and includes part or all of six states.

The Regions have equal responsibility for implementing programs designed to carry out national Agency policies for the preservation and enhancement of environmental quality. I am going to limit my remarks to activities relating to water quality.

NATIONAL POLICY

The 1972 Amendments to the Federal Water Pollution Control Act established national goals and policies for the control of water pollution.

National goals set forth in the Act are: eliminate the discharge of pollutants into navigable waters by 1985, and attain an interim goal by July 1, 1983, of water quality which provides for the protection of fish and wildlife and for recreation.

National policies were established to prohibit the discharge of toxic pollutants in toxic amounts; provide federal financial assistance to construct publicly owned waste treatment works; develop and implement areawide waste treatment management plans; and undertake a major research and demonstration effort to eliminate the discharge of pollutants. Further, the primary responsibilities of the states in water pollution control, and the need for international action to reduce or eliminate pollution, are recognized.

The new amendments represent a significant departure from previous legislation in several respects, so that some of the activities I will describe are still in the formative stage, while others are extensions of existing programs.

EFFLUENT LIMITATIONS

The basic mechanism for achieving the goals and policies of the law is effluent limitations for discharges into navigable waters. Point sources other than publicly owned treatment works must use the best practicable control technology currently available by July 1, 1977. EPA will publish guidelines for effluent limitations which will identify the degree of effluent reduction attainable through use of the best practicable technology currently available.

Publicly owned treatment works in operation on July 1, 1977, or approved for construction prior to June 30, 1974, must meet effluent limitations based on secondary treatment. EPA will publish guidelines defining the degree of effluent reduction attainable through use of secondary treatment.

Also by July 1, 1977, more stringent limitations will be applied when necessary to meet water quality standards, treatment standards, or compliance schedules.

By July 1, 1983, all publicly owned treatment works must use best practicable technology and all other point sources must use best available technology. Also by this date, effluent limitations will require no discharge of pollutants from categories or classes of discharges for which EPA finds the requirement technologically and economically achievable.

Thermal discharges are identified as a separate aspect of the water pollution problem. Although such discharges are regulated under the provisions which apply to any point source, EPA may set a different standard (which must assure the protection of fish and wildlife) for a particular discharge if an owner or operator can show that an effluent limitation proposed for his source is more stringent than necessary to protect fish and wildlife.

PERMIT PROGRAM

The limitations and guidelines discussed above are applied to individual dischargers through a permit program. The Regional Office will issue permits for discharges that meet all applicable effluent limitations and discharge criteria. Effluent data supplied by permit applicants will be verified by field surveys when such information is considered necessary to determine compliance with effluent limitations.

A state may administer the permit program for discharges into navigable waters within its jurisdiction if the program it proposes is approved by EPA.

ENFORCEMENT

Although enforcement of the permit provisions is primarily a state responsibility, EPA has strong authority to act against violators. It is expected that much of the enforcement authority will be delegated to the Regional Offices. If a person is found to be in violation of a state permit, EPA may either (1) notify the person and the state of the finding of violation, and, not less than thirty days later, issue an order requiring compliance or bring a civil action if the state has not acted, or (2) issue an immediate order or bring a civil action. In cases of violation of a federal permit, EPA may either issue an immediate order or bring a civil action.

If violations of permit conditions are so widespread as to appear to result from a state's failure to enforce, EPA will notify the state. If the failure extends beyond 30 days, EPA may enforce permit conditions or limitations until the state is able to do so.

MUNICIPAL WASTE TREATMENT FACILITIES

Financial assistance for the construction of municipal waste treatment plants has been a basic element of the federal water pollution control program for many years, and is administered by the Regional Offices.

The new legislation provides for an increase in the federal share from a maximum of 55 percent to 75 percent of the cost of construction. The Administrator has announced that $2 billion will be available for this purpose in FY 1973, and $3 billion in FY 1974.

In order to be approved for federal funding, a project must be in conformity with the applicable state program plan, be certified by the state as entitled to priority, and be included in the applicable areawide waste treatment management plan. The Regional Office reviews and approves projects for funding which are in compliance with these and other requirements of the law.

RESEARCH

The Regional Offices have an ongoing program to develop research needs designed to provide a better understanding of factors affecting water quality of the Great Lakes, and to develop methods for controlling the discharge of polluting substances. These research needs are used by EPA headquarters in developing Agency research priorities. The Regional Office also has responsibility for eliciting interest in the development and submittal of proposals for research, development and demonstration grants, reviews these proposals, and administers resulting grants.

AREAWIDE PLANNING

The new legislation provides that "to the extent practicable, waste treatment management shall be on an areawide basis and provide control of all point and non-point sources of pollution . . ."

Plans are to be developed by designated planning agencies or by the state which identify necessary treatment works and construction priorities, establish regulatory programs, and identify non-point sources of pollution and measures to control them to the extent feasible. The state will designate one or more waste treatment management agencies for each area covered by a plan. EPA may fund 100 percent of the costs of developing and operating the plan. The Regional Offices will review and approve areawide plans, and administer federal planning funds to be used by planning agencies.

GREAT LAKES PROGRAM

The regional offices have individual or cooperative responsibilities in carrying out programs having specific applications to the Great Lakes.

INTERNATIONAL FIELD YEAR ON THE GREAT LAKES (IFYGL)

The Rochester Field Office of Region II is participating in the Chemistry and Biology Program of IFYGL. The Field Office is performing the routine chemical analyses of all water samples collected by U.S.-IFYGL participants. Samples are analyzed for some 20 parameters, and to date 63,000 analyses have been made.

The Field Office is also responsible for the Materials Balance Program, which has as its goal the determination of the chemical budget for Lake Ontario. Inflow and outflow are sampled every three days and the main Lake is being sampled eight times at 63 stations with an average of 10 sampling depths per station.

GREAT LAKES BASIN COMMISSION (GLBC)

Region V serves as EPA representative to GLBC, and provides coordination with Regions II and III for activities affecting their areas. The Regional Office has prepared three appendixes for the Framework Study: Water Quality;

Water Supply; and Health Aspects. The Region is participating in the formulation of the Framework Plan through membership on the Plan Formulation Committee, and serves on several other committees as well. The Region assisted in funding through a research grant, Phase I of the Limnological Systems Analysis, a study to determine the feasibility of modelling limnological systems in the Great Lakes.

INTERNATIONAL JOINT COMMISSION (IJC)

The Regional Administrator, Region V, serves as Chairman of the U.S. Section of the Great Lakes Water Quality Board, adviser to IJC on water quality problems on the Great Lakes. Region V also has the lead role in carrying out EPA responsibilities under the U.S.-Canada Great Lakes Water Quality Agreement. The Region provides coordination with Regions II and III in these matters. In the lead role, Region V provides EPA membership on working groups carrying out IJC studies of pollution in Lakes Huron and Superior, and of pollution of the Great Lakes from land use activities.

NAVIGATION SEASON EXTENSION DEMONSTRATION PROGRAM

Region V provides EPA participation in the interagency program which is being carried out under the auspices of the Corps of Engineers. EPA is primarily involved in the determination of environmental effects resulting from the demonstration projects undertaken. The Environmental Effects Work Group, chaired by Region V, will prepare the Environmental Impact Statement for the entire demonstration program.

SECTION 108 GRANTS

The water pollution control legislation of 1970 established a grant program to demonstrate new methods and techniques and to develop preliminary plans for the elimination or control of pollution within all or any part of the watersheds of the Great Lakes. This authority is now contained in Section 108 of the new Act. The Regional Offices administer the program, and six projects have been funded for a total amount of about $2.0 million dollars.

LAKE MICHIGAN

Region V has long taken an active role in seeking solutions to water quality problems in the Great Lakes. At a recent meeting with the water pollution control administrators of the four Lake Michigan states, the Regional Administrator proposed for formation of a federal-state technical panel to review the monitoring studies of thermal discharges required under the permit program. The responsibility of the panel would be to:

(1) review background information dealing with past, present and future studies relating to thermal discharges to Lake Michigan;

(2) make assessments as to whether the individual studies concerning

thermal discharges will adequately assess damage attributable to that cooling water use;

(3) assess the pertinence of individual localized studies to monitor changes in the overall lake ecosystem; and

(4) recommend, as necessary, additional efforts that should be expanded to assess environmental effects of the use of Lake Michigan water for cooling.

It appears that this will be a major effort in finding answers to some of the questions relating to thermal pollution of Lake Michigan.

In addition, EPA and the states agreed to take actions to:

(1) reduce chloride discharges to Lake Michigan;

(2) further reduce phosphorus discharges to Lake Michigan by adopting an effluent limitation of 1 mg/1 total phosphorus for municipal effluents from plants with a population equivalent of 2,500 or greater;

(3) assist the Bureau of Sport Fisheries and Wildlife in continuing and intensifying fish sampling for establishing trends in pesticides residues;

(4) identify all significant sources of PCB in the basin and eliminate or reduce each such discharge to an absolute minimum, and institute monitoring programs to gauge the effectiveness of control programs;

(5) initiate surveillance to determine phthalate trends in the aquatic environment, and accelerate research to determine levels that are toxic to aquatic organisms;

(6) determine inputs of selected trace metals to Lake Michigan from point sources, reduce inputs of such metals to the maximum practicable extent, and give high priority to research to develop acute toxicity levels for Lake Michigan fish; and

(7) establish a Toxic Substances Committee to evaluate and report on the nature, extent and relative toxicities resulting from the use and subsequent discharge of any and all toxic substances.

The foregoing is a summary of the activities of EPA Regional Offices, and is not to be construed as all-inclusive. The implementation of many activities authorized by the new legislation will depend to a great extent upon the availability of resources. I believe that it is safe to assume, however, that the Regional Offices will continue to be very active in the Great Lakes for many years.

Ancillary Research Activities of EPA

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Norbert A. Jaworski, National Environmental Research Laboratory,
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ABSTRACT

The U.S. Environmental Protection Agency (EPA) conducts research through its four National Environmental Research Centers and their associated laboratories in four general areas: (1) ecology, (2) pollution control technology, (3) health effects, and (4) monitoring. While two of EPA's 139 research program elements, large lakes and Great Lakes research, are directly dedicated to the environment of the Great Lakes, many of the remaining program elements also are related either directly or indirectly to the Great Lakes. (A program element is the smallest unit for planning resources and objectives by EPA.) Of the remaining, the following program elements conduct ecological research, part of which is directly related to the waters of the Great Lakes and their tributaries:

Program Element	Laboratory Location
Ground water	Ada, Oklahoma
Coastal pollution	Corvallis, Oregon
Thermal pollution	Corvallis, Oregon
Eutrophication	Corvallis, Oregon
Fresh water, other fresh water life, and wildlife	Duluth, Minnesota
Surface water pollution	Athens, Georgia

All of these programs are under the National Environmental Research Center at Corvallis, Oregon.

The major emphasis of this paper will be on the ecological research program. Budget and staff resources for the Great Lakes portion are prorated from total effort.

* * *

INTRODUCTION

EPA's research falls into four main categories: the processes and effects of pollutants; the technology to abate pollution; the results of pollution abatement; and man's long-range impact on the environment. The implementation of EPA's research program is conducted by four National Environmental

Research Centers (NERC's). The NERC's are located in Research Triangle Park, North Carolina; Cincinnati, Ohio; Corvallis, Oregon; and Las Vegas, Nevada. Under the NERC's jurisdiction, 42 full-fledged laboratories located in eighteen states from Florida to Alaska are conducting research on air, water, pesticides, solid waste, and radiation.

At each NERC, there is a central theme of research. The themes for the four NERC's are: Corvallis, ecology, Cincinnati, pollution abatement technology; Research Triangle Park, health effects; and Las Vegas, monitoring.

The following program elements, within the theme of control technology, conduct research related to pollution abatement methods applicable to the Great Lakes drainage Basin:

(1) municipal sewer discharges
(2) combined sewer overflows
(3) heavy industrial sources
(4) food, pulp and other sources
(5) agriculture sources
(6) hydrologic modification

These activities, which are located at various laboratories, are under the management of the National Environmental Research Centers at Corvallis and Cincinnati.

RESEARCH PROGRAMS

Ground Water (Robert S. Kerr Environmental Research Laboratory, Ada, Oklahoma)

One of the research programs at the Robert S. Kerr Environmental Research Laboratory is the national ground water research program which has the responsibility for directing and implementing field, laboratory, and extramural research activities of the program element, Fate of Pollutants in Ground Water.

The main goals of the program are (1) to increase the state of knowledge of the fate of pollutants in the subsurface environment, (2) to provide a rational base for subsurface waste injection decisions, and (3) to provide technology for the prevention of ground-water pollution or the restoration of polluted ground-water resources from natural or man-made causes.

Major research efforts of fiscal year 1973 are concerned with (1) providing a better definition of the subsurface physical, chemical, and biological environment, (2) investigating the subsurface fate of several organic pollutants from lagoons, landfills, and septic tanks including a search for an organic indicator of fecal contamination, (3) developing advanced ground-water investigation techniques, and (4) continuing effort to more closely define national ground-water pollution problems so that research goals may be adjusted accordingly.

The program also provides technical assistance to Regional Administrators, states, universities, consultants, and headquarters on topics such as wastes application to the land, subsurface waste injection, and the fate of pollutants in ground water. In the Great Lakes Basin, assistance is being provided in the soil application of wastewater such as the Muskegon, Michigan, project and the U.S. Corps of Engineers proposals for Detroit and Cleveland.

Coastal Pollution (Pacific Northwest Environmental Research Laboratory, Corvallis)

At the Pacific Northwest Environmental Research Laboratory (PNERL), the National Coastal Pollution Research Program has the responsibility for directing and implementing field, laboratory, and extramural research activities of program element Fate of Pollutants in Marine Waters. Many of the program activities have been historically associated with the Great Lakes in that the Great Lakes are considered by Congress to be part of the marine environment.

The main goals of the program are to improve scientific understanding of pollutant behavior in the marine environment and to provide a rational basis for marine water quality criteria and waste discharge decisions. Major research areas are related to (1) evaluating acceptability of materials proposed for marine disposal, (2) identifying allowable discharge sites for acceptable materials, (3) monitoring and assessing damage to marine water quality, (4) restoring water quality in polluted coastal regions, (5) finding beneficial marine uses for materials wasted to the environment, and (6) developing predictive techniques to describe the time-space distribution of pollutants as influenced by physical transport and dispersion, chemical interactions and transformations, and biological interactions and transformations.

Major research efforts during fiscal year 1973 are concentrated in four geographically important coastal areas: (1) effects of digested municipal sewage sludge dumped in the New York Bight, (2) effect of treated municipal sewage discharges in the Los Angeles Bight, (3) heavy metal transport and accumulation in Southeast coastal ecosystems, and (4) persistent organics and other pollutant accumulations in Puget Sound. The research involves a mix of physical, chemical, and biological interactions and the development of predictive models for applications to other coastal areas.

Technical assistance in the areas of oceanography, coastal engineering, and coastal pollution is provided to other research programs and regulatory sections of the agency, to state and municipal governments, and to universities and private firms. During 1972, the major effort of the coastal pollution program was on the enforcement activities associated with Lake Superior.

Thermal Pollution (Pacific Northwest Environmental Research Laboratory, Corvallis)

The National Thermal Pollution Research Program, located at PNERL, has the responsibility for directing and implementing EPA's field, laboratory, and extramural activities relating to thermal pollution control.

The major goal of the thermal pollution research program is the improved scientific basis for predicting and assessing the amount, behavior, and physicochemical and biochemical effects of heat discharged to the aquatic environment including development of environmental systems for safe management of heated discharges, siting requirements for heat discharging plants, and beneficial environmental uses of otherwise wasted heat. Another major goal is development and demonstration of methods for preventing, controlling, and abating thermal pollution.

In the thermal pollution research program element, current emphasis is placed on analytical and laboratory work leading to improved predictive models used to describe the hydraulic and thermal characteristics and the environmental impact of heated water discharges, both near the discharge point and far afield. Present high priority research also involves an investigation of the opportunities for multiple use and recycling within thermal power plants, as well as work on the control of drift and blowdown from wet, closed-cycle cooling systems.

The program also provides technical assistance relating to the interpretation of data, review of proposals for disposal of waste heat, state-of-the-art for thermal pollution control, and design of investigations. The program has provided technical assistance in enforcement actions in Lake Michigan and is involved with environmental impact statements dealing with power production for all of the Great Lakes.

Eutrophication (Pacific Northwest Environmental Research Laboratory, Corvallis)

Another activity at PNERL is the National Eutrophication Research Program which has the responsibility for directing and implementing field, laboratory, and extramural research activities of program element, eutrophication and lake restoration.

The major goal of the program is the development of eutrophication controls for freshwater and marine environments. Specific objectives are (1) to develop an understanding of the eutrophication processes, (2) to develop methods for monitoring eutrophication conditions and for predicting the impact of nutrient sources on eutrophication, (3) to develop technology to control and reverse eutrophication processes, and (4) to establish the practicability of using this technology through pilot and demonstration scale application.

Major research activities are currently directed toward an intensive lake restoration project at Shagawa Lake, Ely, Minnesota, involving phosphorus removal from waste effluent, development of mathematical models of the eutrophication process, development of methods for controlling nutrients from diffuse sources, development and application of assay procedures for use in studying and solving eutrophication problems, and the development of methods to inhibit the growth of algae and higher aquatic plants when nutrient input cannot be controlled.

The program also provides technical assistance in the areas of algal assay methodology and determinations, provides algal cultures to other institutions, and advises on methods to monitor eutrophic conditions. It also provides general consultation to the enforcement actions in Lakes Michigan and Erie.

In addition to other activities, numerous grants have been awarded to universities in the Great Lakes Basin. Most of these grants are related mainly to fundamental problems of eutrophication.

Lake Survey (Pacific Northwest Environmental Research Laboratory, Corvallis)

The National Eutrophication Survey Program was initiated in 1972. The program activities which involve the smaller lakes of the nation including those of the Great Lakes Basin are being conducted jointly by Environmental Surveillance Program of NERC-Las Vegas and the Pacific Northwest Environmental Research Laboratory.

The primary objective of the National Eutrophication Survey Program is to identify those lakes and impoundments receiving effluents from municipal sewage treatment plants (MSTP) and, in each case, to determine whether phosphorus reduction in the MSTP effluent(s) would improve the trophic state of the receiving water body. This objective is accomplished by a lake sampling program extending over one growing season to evaluate the existing trophic condition of each water body, algal assays to determine whether phosphorus is the limiting nutrient in each water body, and a tributary and MSTP sampling program of one year for each water body to estimate the relative nutrient inputs from MSTP's versus other nutrient sources. Lake water sampling and analysis are conducted by NERC-Las Vegas and all other aspects of the program are the responsibility of PNERL.

The current activities of the program include studies of approximately 220 lakes in ten states including seven New England states plus Michigan, Minnesota and Wisconsin. In 1973, approximately 340 lakes in the remaining seventeen states east of the Mississippi River will be added to the survey.

Water Quality Criteria (National Water Quality Laboratory, Duluth, Minnesota)

The Federal Water Pollution Control Act of 1948, as amended by the Congress in 1961, established the National Water Quality Laboratory. This Act further established the objective of the laboratory, which was the development of water quality criteria for freshwater uses in the United States. When construction of the laboratory finally became a reality, it was obvious that an excellent water supply would be needed to conduct the research to develop these criteria. Duluth, Minnesota, was selected as the point for the location of the laboratory, since water from Lake Superior would be used for this research.

There are presently two operational field stations. The Newtown Fish Toxicology Laboratory near Cincinnati, Ohio, is operated to provide facilities and expertise to work with warmwater biota characteristic of the southeastern part of the nation. It is also in the heart of a large industrial valley and future work will revolve principally around complex industrial waste research related to effluent standards. The Western Fish Toxicology Laboratory, on the banks of the Willamette River in Oregon, is the world's first and only adult salmon toxicity testing facility. This laboratory is designated for research on anadromous fish, particularly those characteristic to the Northwest region, such as the salmon and steelhead.

A third field station will be completed in the fall of 1973 at Monticello, Minnesota, thirty-five miles up the Mississippi River from Minneapolis. Eight experimental channels, approximately one-third mile long, are being constructed and temperature can be controlled to study the effects of entrainment, thermal plumes, and altered temperature regimes on entire aquatic ecosystems. Cooperative research with other programs, such as the thermal research program is anticipated in this facility.

Currently, the National Water Quality Laboratory has one program element, Freshwater Fishes, Other Freshwater Life, and Wildlife, which is performing research to establish the necessary criteria to protect a viable aquatic environment.

Twelve research objective achievement plans (ROAP's) have been prepared to aid, in part, the establishment of these water quality criteria. Three of these ROAP's are totally extramural and include hydrogen sulfide, ammonia and effluent test site evaluation. The major emphasis of a fourth ROAP utilizes grants with a minimal in-house effort to evaluate the effects of chlorination as a means of disinfection of sewage effluents. The predominant research areas are (1) development of bioassay data for support of requests by Headquarters and Regional offices, (2) verification of laboratory-derived data by natural ecosystem studies, (3) determination of effects of synthetic organic chemicals and heavy metals, and (4) determination of temperature and dissolved oxygen requirements of aquatic life.

Two ROAP's consume a major portion of the research efforts of the laboratory and are involved in the development of biological test methods and short cut methods to determine toxicant criteria.

There are two central themes in the research program presently underway. One theme has as its objective the development of numerical data that can be used to formulate water quality standards and effluent standards, data for evaluation of environmental impact statements and toxicity data particularly suited for such uses as in the Hazardous Substances Control Program. The second theme of the research program is to develop, test and standardize techniques, methodologies and protocols so that the number of laboratories and individuals who can perform bioassays can be increased to meet the growing demand.

At the present time, over one-half of the research program is directed at specific problem areas, particularly those related to court cases and enforcement actions from coast to coast, and in most of those instances, the work being done has been done at the specific request of some EPA region or agency. Included in these specific study areas are the enforcement activities of Lake Michigan and special studies of Lake Superior.

Surface Waters (Southeast Environmental Research Laboratory, Athens, Georgia)

One of the research program elements at the Southeast Environmental Research Laboratory (SERL) which is related to the waters of the Great Lakes Basin, is the fate of pollutants in fresh surface waters.

The overall goal of this research is to establish a scientific basis for predicting the fate of pollutants that enter fresh surface waters from various sources, and for assessing the potential exposure of human and aquatic life to these pollutants. This research examines, for lakes and rivers, the distribution, the pathways, and the rates at which pollutants move, accumulate, and degrade, including the chemical, physical, and biological factors that influence these phenomena. This research will produce mathematical models describing the interrelated components and processes of aquatic ecosystems and predicting the fate of freshwater pollutants. The data from fundamental studies of pollutant chemistry, biology, and physics and ecosystem processes will support the formulation of rational water quality and effluent standards.

At Athens, a $750,000 ecosystem simulator is beginning to be used to examine movement through various aquatic systems. The simulator is an actual water course for which most variables such as aeration, mineral content, diurnal cycles (sunlight, temperature, etc.) and turbidity can be controlled.

Past studies in the Great Lakes Basin have been mainly extramural dealing with the contribution of pesticides from runoff. Extramural support was also provided for a physical model of Lake Ontario.

Current major program efforts include the following tasks:

(1) Develop techniques for studying the fate of classes of pollutants.
(2) Develop predictive models describing the fate of specific pollutants.
(3) Identify chemical, microbial, and photochemical degradation processes, products, and rates.
(4) Compile a catalog of pollutants classified according to mode of removal and persistence.

The major focus of the research effort related to the Great Lakes is on how pollutants are transported from the drainage basin into confines of the five Great Lakes.

RESOURCES

For EPA's ancillary research program the total resources for fiscal year 1973 for the program elements are as follows:

Program	Man Years	Budget
Ground Water	9	$ 460,000
Coastal	17	1,170,000
Thermal	9	650,000
Eutrophication	22	1,910,000
Lake Survey	48	1,800,000
Water Quality Criteria	65	3,550,000
Surface Water	14	750,000
Total	184	$10,290,000

Assuming that effort which is directly or indirectly related to the Great Lakes Basin can be prorated according to population, the Great Lakes portion of the resources for the ancillary research program is estimated to be about 25 man-years and $1,500,000 for fiscal year 1973. For fiscal year 1972, the level of funding was about the same as for fiscal year 1973. It is anticipated that fiscal year 1974 will be about at fiscal year 1973 level.

FUTURE EFFORTS

For the ancillary research effort of EPA, it is anticipated the future will be similar to current programs. A closer cooperation effort within EPA will be maintained through the two new program elements, that is, Great Lakes and large lakes research programs.

Overview of the Programs in the Great Lakes of the United States Corps of Engineers

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ABSTRACT

The Chief of Engineers of the U.S. Army Corps of Engineers heads the world's largest construction agency. In the Great Lakes Basin the North Central Division (NCD) Engineer is responsible for a large civil works program including planning, design, construction, operation, and maintenance of coastal and waterways projects to satisfy regional needs, such as controlling urban flood damages, protecting shores against erosion, improving navigable waterways for modern shipping, abating pollution, and improving water-oriented recreation. The Division Engineer represents the Department of the Army in matters concerning planning and development of water resources on International Joint Commission Boards and Working Committees and on the Great Lakes Basin Commission. The Division Engineer also insures response to national emergencies in river and coastal flooding and manages the permit program for construction in navigable waters.

The future program of the North Central Division includes studies on comprehensive basin analysis; navigation for deep and shallow draft channels and harbors; wastewater management; shore protection projects and IJC; design, construction, operation and maintenance of navigation channels and harbors and of local flood protection works.

Performance of the Corps' mission in the Great Lakes is accomplished with an eye towards improving quality of the end product wherever possible. Engineers of NCD employ modern engineering techniques in all phases of their work but are continually finding that additional information or modified techniques, if they were available, could improve quality. These needs are presented on a systematic basis through the Chief of Engineers. Needs with the greatest payoff are identified and assigned to the various Corps' laboratories for research and development.

Research and specialized engineering for water resources is conducted for NCD under the direction of three separate activities. They are: U.S. Army Coastal Engineering Research Center (CERC), U.S. Army Engineer Waterways Experiment Station (WES), and U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). Each of these separate activities has a specific and non-overlapping function designed to support the total Corps mission.

* * *

THE CORPS OF ENGINEERS

The Chief of Engineers is the systems manager for engineering support for the Army, and he heads the world's largest and most versatile construction agency. Coastal and waterways planning, design, construction, maintenance, and operation is directed by the Chief of Engineers as manager of the nation's comprehensive water resources program—the Army Civil Works Program.

The Chief of Engineers has field agencies and a headquarters staff to help him carry out his duties. The Office of Chief of Engineers is composed of four operating directorates, ten technical and administrative offices, and special advisors, boards and commissions. The decentralized field agencies are spread throughout the world. There are 13 Division and 37 District Offices commanded by Engineer officers and staffed primarily by civilian employees.

Civil works activities of the Corps are conducted in response to a two-step mandate. Our primary direction is taken in response to specific laws passed by the Congress, and those laws are created in response to people's needs. Studies and planning are coordinated with the states and other federal agencies. Environmental effects are given full consideration.

Laboratories under the Chief's direction and command are engaged in research for improved techniques for use in civil works construction, studying problems in hydrology and hydraulics, conducting research into ice engineering, conducting studies in material and soils mechanics, and research to develop better protective coastal works and shore structures.

THE CORPS' MISSION IN THE GREAT LAKES BASIN

Corps of Engineers activities in the North Central portion of the United States are managed by the North Central Division (NCD). NCD's area of Civil Works responsibility covers the area from North Dakota to the St. Lawrence River and from the Canadian border to within 50 miles of St. Louis, Missouri. This includes the Great Lakes Basin, the Upper Mississippi River valley, and the watersheds of the Souris, Red, and Rainy Rivers in northern Minnesota and North Dakota.

This presentation is limited to the Corps' civil works engineering activities and research in the Great Lakes Basin. These include planning, engineering, construction, operations, and maintenance directed at:

1. flood control;
2. control of eroding shorelines;
3. improvements for navigation;
4. regulation of Great Lakes levels;
5. managing the permit program for construction in navigable waters;
6. flood plain information;
7. comprehensive studies of regional problems such as wastewater management;
8. cleanup of Lake Erie;

9. extension of the navigation season on the Great Lakes and the St. Lawrence Seaway;
10. Basinwide studies for control of floods;
11. restoration of polluted rivers.

Deep draft navigation facilities on the Great Lakes maintained by the Corps of Engineers include 64 harbors, 157 miles of improved channels, and the quadruple locks of the St. Marys Falls Canal. Our annual maintenance effort employs 900 government personnel in the field and approximately 300 contractor personnel. To maintain navigation channels on the Great Lakes the Corps has 37 major pieces of floating plant, including four hopper dredges and eight dipper and bucket dredges.

Maintenance of the channels and harbors requires dredging over 10 million cubic yards of shoal material in a normal year. Concern over the effect of polluted dredge spoil on the Lake environment has limited dredging activity for the last four years. The impact of that concern has been to reduce dredging to 7 million cubic yards per year. We are adhering to our policy of avoiding open Lake disposals of polluted dredge spoil.

Intensive planning for construction of contained disposal areas for polluted dredge spoil is under way. EPA has determined that 47 deep draft harbors on the Great Lakes have polluted bottom sediments which will require contained disposal. Including the connecting channels and small boat harbors, there are 75 navigation projects on the Great Lakes for which contained disposal must be provided.

Shore erosion is a problem of major concern on the Great Lakes. The United States shoreline of the Great Lakes is about 3,700 miles long. About a third of that shoreline is experiencing significant erosion, and only 10 percent of the shoreline is protected. The State of Michigan alone considers 400 miles of its shoreline to be experiencing serious erosion. Waves generated during storms cause great damage and investment loss to shore developments, recreational beaches, industrial areas, and harbor entrances, and they may result in loss of life.

A powerful tool for management of eroding shorelines is knowledge of the amount of erosion that can be anticipated in the future. General information about shoreline changes shown in the regional inventory report of the National Shoreline Study needs to be supplemented with more specific information about rate and extent of shoreline erosion. Such predictions for the 3,700 miles of Great Lakes shoreline are few and far between. One example of beneficial predictions is 30 miles of Lake Superior shoreline in Ontonagon County, Michigan. Shoreline erosion was predicted for the next 50 years and is shown in our "1970 Report on Flood Plain Information for Ontonagon River and the Lake Superior Shoreline of Ontonagon County." The prediction of rate and extent of shoreline erosion was based on knowledge of erosion that occurred in the last 100 years, considering lake levels and wave heights. Local governing bodies have already found the predictions to be very useful in their management of the shoreline of Ontonagon County.

Purity of the Great Lakes is a national concern that is reflected in recent resolutions and legislation about wastewater management. The legislation included authority for comprehensive studies of the metropolitan areas of Chicago, Detroit and Cleveland by the Corps; design and development of a "Lake Erie Demonstration Program;" and consultation with and provision for technical assistance in developing and operating a continuing areawide waste treatment management planning process.

General alternatives for management of wastewater on a regional basis at Chicago, Detroit and Cleveland are being evaluated by the Corps. The studies are intended to determine the advisability of improvements and include means for eliminating pollutant discharges from the three major metropolitan areas in the Great Lakes Basin.

Congress showed particular concern about serious conditions on Lake Erie in the recent amendment to the Federal Water Pollution Control Act (Public Law 92-500 dated 18 October 1972). As a result, the Corps of Engineers was given the responsibility for the "Lake Erie Demonstration Program" in which the Secretary of the Army, acting through the Chief of Engineers, is directed to design and develop a demonstration wastewater management program for the rehabilitation and environmental repair of Lake Erie. Five million dollars is authorized to carry out the demonstration program. This study will require close cooperation with federal, state and local agencies and departments.

Technical assistance to states for developing and operating an areawide waste treatment management plan is also provided in the 1972 amendment to the Water Pollution Control Act (P.L. 92-500). Fifty million dollars is authorized to be appropriated in fiscal years 1973 and 1974 to carry out this authority.

The program for extending the navigation season on the Great Lakes and the St. Lawrence Seaway offers an exciting possibility of increasing the usefulness of the Great Lakes navigation resource. From April through November the Great Lakes and the St. Lawrence Seaway bustle with waterborne commerce. But from December through March the Lakes and Seaway are ordinarily locked in the grip of ice. Traditionally, the vast machinery and facilities of waterborne commerce of the nation's fourth seacoast and most of the people who run them have been idle for one third of the year.

In 1970 Congress authorized a three-year, $6.5 million program to demonstrate the practicability of extending the navigation season on both the Great Lakes and the St. Lawrence Seaway. The authorization requires a report to Congress by 31 July 1974. Eight federal agencies are participating in the three-year program. To direct the program, the Winter Navigation Board was formed. The board is chaired by the Corps of Engineers.

The program for extension of the navigation season began last winter, and navigation was extended later than ever before. Ships continued to transit the St. Lawrence Seaway from Lake Ontario to Montreal until 20 December and used the Welland Canal between Lake Erie and Lake Ontario until 7 January. Ore ships passed through the locks at Sault Ste. Marie between Lake Superior and Lake Huron until 1 February, an all-time record for late season navigation.

Ice management in channels, locks, and harbors is the practical application of ice engineering and ice control techniques to enable winter navigation in confined areas. The Detroit District of the Corps of Engineers is the lead agency in this effort as a part of the ongoing program for extension of the navigation season.

Light draft harbors serve as home ports or as harbors of refuge for commercial and recreation vessels. Today there are about 215 harbors on the U.S. shores of the Great Lakes serving boaters using light draft vessels. These include 50 non-federal or natural harbors, 15 harbors of refuge, 102 light draft harbors and 62 commercial deep draft harbors.

Today there are about one million recreational boats in the Great Lakes region, and in the next 50 years there may be four million. Most of the Great Lakes waters are not available to small boats. We find most boating activities take place within four miles of existing harbors. Thus, proper siting of boat harbors can greatly increase the boatable waters of the Great Lakes.

Our policies are directed at unlocking the underused waters of the Great Lakes for the future needs of recreational and commercial boating. A systems approach to the problem is already indicated. Our greatest opportunities to enhance boating on the Great Lakes exist near the large metropolitan areas, which are given high priority in planning.

Regulation of two of the five Great Lakes within limits of predetermined rule curves is accomplished under the authority of the International Joint Commission. Lakes Superior and Ontario are regulated. The Division Engineer of NCD is chairman ex-officio of the Monitoring Boards for Lakes Superior and Ontario. As chairman of the Superior Board he supervises operations of all compensating works and all power canals and appurtenances with a view to so controlling the outflow from Lake Superior as to maintain its levels within specified limits. As chairman of the St. Lawrence River Board he is responsible for the determination of measurements and other services to be provided by the power entities in order to furnish accurate records relating to water levels and discharge through the works and the regulation of the flow of water through the International Rapids section. The Board also must keep the Commission informed with regard to the discharge of water from Lake Ontario and the flow through the International Rapids section of the St. Lawrence River. In line with the Corps' policy of decentralization, monitoring activities are performed for the Boards by Corps of Engineers' District representatives who provide field coordination with Canadian counterparts. Situations involving policy questions are referred to the Board for resolution.

The federal program of permits for construction in navigable waters is managed by the Corps of Engineers. The Corps insures that all public and private interests are given an opportunity to impact on the decision to grant or withhold such permits. In cases where permit applicants cannot obtain agreement of objections against construction, the permit is either denied or else the Corps holds public hearings to provide a basis for judgment.

CORPS RESEARCH RESPONSIBILITIES

Planning of public works in the coastal zone today is not simple, if indeed it ever was. Increasing sophistication demands increasing research effort, and the knowledge gained from research further increases sophistication. The pattern is circular and endless. In support of its civil works mission the Corps is heavily committed in the research area. Current research at WES and CERC is looking into such diverse matters as energy transfer at the air-water interface, spoil disposal effects, effects of construction activities on the ecology of the coastal zone, littoral processes, computer simulation of current behavior, wave generation, propagation and attenuation, dune stabilization, and many others. The Cold Regions Research and Engineering Laboratory is the lead agency for ice engineering, aimed at improving the design of structures to resist ice forces and to control ice at its various stages of formation and breakup. The Waterways Experiment Station at Vicksburg, Mississippi, one of the largest hydraulic laboratories in the world, is conducting research about harbors and channels and other works. Their physical and mathematical models provide needed answers to our engineers about the effects of modifications to the shorelines on currents, littoral patterns, wave energies, and erosion.

Each engineering and research facility publishes the results of its investigations for dissemination to Corps engineers and other interested individuals. Most of these publications contain information that can be found nowhere else.

The Coastal Engineering Research Center and the Waterways Experiment Station are respected worldwide for their contributions to knowledge of the coastal zone. For example, the Corps technical report, *Shore Protection, Planning and Design*, is the definitive text on this subject internationally. The third printing of this report is sold out and the report is currently undergoing extensive revision to make it even more useful to practicing engineers. The new technical report will be titled *Shore Protection Manual*.

FUTURE CORPS PROGRAM

The future direction of the Corps of Engineers Program for Civil Works will continue to reflect national needs. Both structural and management solutions to problems are considered as a recognition that the full extent of water resource problems cannot be cured only by structural methods. The optimum solution of regional problems is usually found to lie somewhere between full management and full structural alternatives. The national interest in urban water management problems is reflected in several ongoing programs and planned studies aimed at developing carefully conceived plans which are responsive to national priorities. Emphasis is being placed on comprehensive studies and on multiple-purpose projects which include features and uses to satisfy most people's needs in water resources. Several authorized ongoing studies indicating this trend include comprehensive wastewater management studies for the metropolitan areas of Chicago, Detroit and Cleveland, cleanup of the Cuyahoga River basin in and near Cleveland, extension of the Great Lakes navigation season, Lake Erie demonstration, and contained disposal areas.

SATISFYING NATIONAL NEEDS THROUGH ENGINEERING AND RESEARCH

The Corps role in marine science of the Great Lakes is primarily that of the engineer, in its broadest sense. Engineers take the discoveries of man and use them to satisfy the wants of men. The engineer is a customer of science and makes his demands known by focusing priority on the knowledge gaps which need to be filled. His product has significance only to the extent that it corresponds with their wants. He projects trends, population, wealth, attitudes and other factors and tries to see the future through them. He responds to the question, what should we be doing now out of consideration for that future? He works with many other disciplines on these problems, and when he thinks he has some of the systems worked out, he approaches his customers, the people, and says, "Here's what we think would be required to pay for it in income expended—or in benefits foregone. Now tell us what you think."

And people do, but often with not enough concern. Many do not like this projected future. They sometimes loudly clamor for a type of future which they quietly refuse to underwrite at the voting booth in tax assessments or in their individual and collective expenditure patterns.

Sometimes the engineer gets a clear public feedback. More often his approaches, conclusions, and plans evolve as people's awareness of themselves evolves.

It is part of our business to insure that adequate research is accomplished to provide the knowledge and techniques required by our engineers to plan, design, construct, operate and maintain those improvements desired by the people. It is another part of our job to insure that the engineers of the North Central Division apply the knowledge that is gained from research and investigation.

The fiscal year 1973 appropriation of $10.5 million for research conducted by the Corps in its Nationwide Civil Works Program is being used in five major research programs:

(1) Coastal Engineering Research and Development Studies, a primary element of the important coastal zone sector of the Federal Marine Science and Engineering Program, supports the Corps involvement in protection and enhancement of coastal zone resource values. A wide variety of problems are attacked with these funds including wave action, beach nourishment, sediment transport, heat dispersion, modeling technology, ecology, tidal hydraulics, navigation and inlet studies. Continuing improvement of physical and mathematical models helps our engineers to provide needed answers about the effects of modifications to channels, harbors and the shoreline on currents, littoral patterns, wave energies and erosion.

(2) Engineering studies are aimed at improving cost effectiveness, reliability and safety in planning and program execution through continuing analysis of information acquired from projects designed and constructed by the Corps. Engineering studies are also used to exploit and adapt for Civil Works use promising new technologies such as remote sensing, already well proven for othe applications.

(3) Plan formulation and evaluation studies are used to develop, validate and improve methodologies for identifying and measuring needs, in keeping with the increased emphasis upon environmental, social and economic objectives.

(4) Improvement of operations and maintenance techniques fosters more economical and effective accomplishment of the operation and maintenance workload, which is rapidly growing in size and complexity.

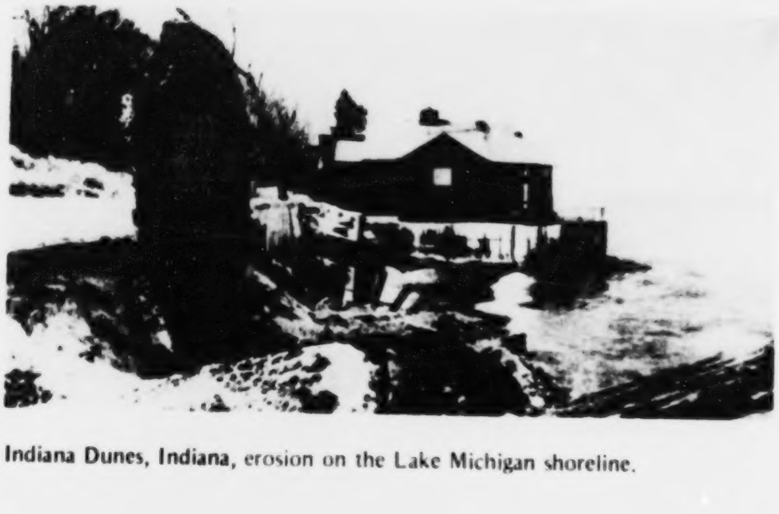
(5) Water quality improvement studies assure that the changes induced in stream, lake, and estuary regimes by Corps impoundments and its other activities improve, rather than adversely affect water quality and related values. The water quality index studies also insure proper identification and evaluation of viable alternatives in planning of wastewater management as an integral component of urban and regional planning for water resource development.

Much of the expertise acquired by CRREL has direct application to current problems of the Great Lakes Region. This has recently been recognized by the Corps of Engineers, and the laboratory is active in the study of the extension of the navigation season on the Great Lakes. The specific studies being pursued on that project are measurement of forces on ice booms, measurement of ice forces on waterfront structures, and measurement of horizontal and vertical ice forces on piling.

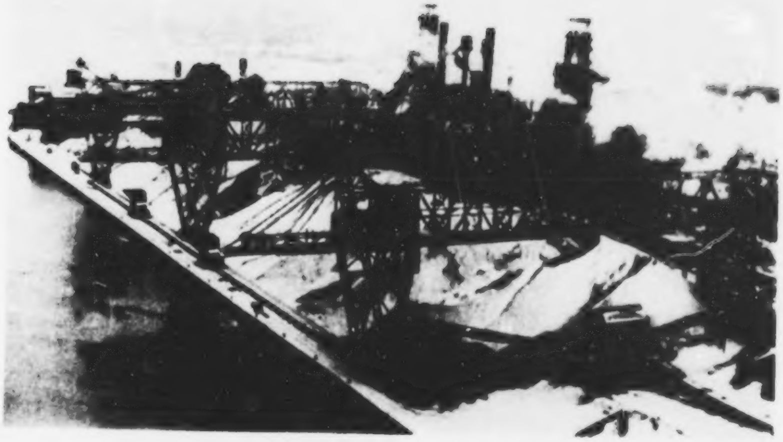
Research and development within the Corps of Engineers is aimed at satisfying the needs of the Corps in accomplishing its mission. Although funds have been limited and additional funds could be beneficially used, engineers thoughout the world look to findings from our research and development studies to gain guidance in engineering for works in the coastal zone. We will continue to apply our best talents in research and development and to ensure that knowledge is found as expeditiously as possible and applied as wisely as it can be.

Holland Harbor, Michigan, developed for multiple uses.

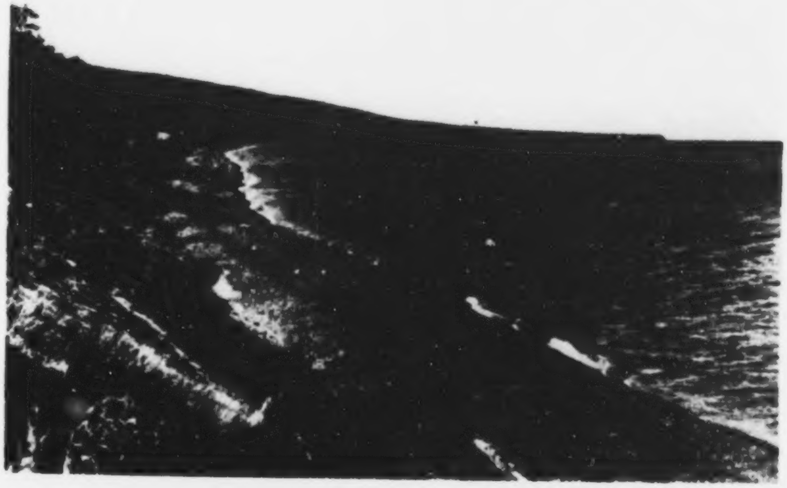
Toledo, Ohio, disposal area for dredged materials.



Indiana Dunes, Indiana, erosion on the Lake Michigan shoreline.



Detroit, Michigan, industrial use of the shoreline (photo courtesy of Michigan Department of Natural Resources).



Lake Superior shoreline (photo courtesy of Michigan Department of Natural Resources).

Saginaw Bay, Michigan, ice damage to a shorefront cottage (photo courtesy of Michigan Department of Natural Resources).

Grand Haven, Michigan, recreational use of the shoreline.

Coastal Engineering Research Program—Great Lakes Applications

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ABSTRACT

The United States Army Coastal Engineering Research Center (CERC) is the research and development facility of the Corps of Engineers in the fields of coastal engineering and coastal ecology. Through basic and applied research and development of methods and techniques, CERC assists in the accomplishment of the Civil Works program of the Corps of Engineers, and in devising means of preventing erosion of coastal and lake shores by waves and currents, in improvement of coastal and harbor navigation channels and facilities, in the protection against flooding and wave damage by hurricanes and other severe storms, in the determination of effects of coastal projects on the ecology of the coastal zone, and the mitigation or enhancement of these effects by engineering methodology. This research and development program is carried out in the laboratory, in the field, and through analytic and theoretical developments. It is carried out in-house and through out-of-house sponsored research at other federal agencies, universities, and various commercial organizations.

Much of the research involves dealing with wave action, shore processes, storm surge and other long period waves, functional and structural design, effects of engineering projects on the physical and ecological environment. Collection of regional data on shore materials and characteristics, and even the hydraulic characteristics of inlets and their effects on sedimentation are applicable to the Great Lakes shores as well as to the open coast or estuarine shores of the rest of the United States. A "Great Lakes Program" is therefore not distinct from the overall program of coastal engineering research.

Until 1970 the Lake Survey District of the Corps of Engineers had a major responsibility in carrying out coastal research in the Great Lakes. In 1970 this office was transferred to the National Oceanic and Atmospheric Administration, becoming the Lake Survey Center. That portion of its mission dealing with research on shore processes, and the effects of various applied forces (such as waves and currents) and of engineering structures on the shore and coastal area was retained by the Corps. That part of its mission pertaining to the physical characteristics of water motion *per se*, that is, the determination of waves and currents in the Great Lakes, their generation and

distribution in time and space, was transferred from the Corps of Engineers to NOAA. Yet, since one affects the other, it is difficult to separate the two missions or to carry them out independently.

Studies currently underway which are pointed specifically at immediate Great Lakes problems, and which are somewhat different from projects applicable to all coastal areas, involve the effect of long-term lake level changes on shore erosion and the development of coastal features (such as the longshore bar system), and the effect of harbor entrances and associated currents on sedimentation processes in the harbor area (particularly on offshore bar development, and harbor shoaling or loss of sediment to the littoral regime through this bar development). Other work specifically pointed at the Great Lakes is the gathering of shore data through a Littoral Environmental Observation program, and the evaluation of effectiveness and maintenance requirements of certain coastal projects such as the beach fill and groins at Presque Isle, Pennsylvania, and the navigation improvements at Burns Harbor, Indiana. Important previous work has been the determination of wave climate throughout the five Lakes by hindcast methods from meteorological charts, and the study of wave pressures exerted on a vertical caisson breakwater.

* * *

The United States Army Coastal Engineering Research Center (CERC) is the research and development facility of the Corps of Engineers in the fields of coastal engineering and coastal ecology. The CERC mission is shown in Figure 1. It is through basic and applied research and development or improvement of methods and techniques that CERC assists in the accomplishment of the Civil Works program of the Corps of Engineers. CERC's principal efforts are directed towards devising means of preventing erosion of coastal and lake shores by waves and currents; improvement of coastal and harbor navigation channels and facilities; protection of coastal areas against flooding and wave damage by hurricanes and other severe storms; and the determination of effects of coastal projects on the ecology of the coastal zone. This program is conducted in the laboratory, in the field, and through analytic and theoretical developments. Research is accomplished in-house as well as by agreement or contract with other federal agencies, universities, and various private organizations.

Information emanating from this research program is published in a series of CERC publications and the scientific literature of professional societies and journals. These publications range from basic theoretical formulations through direct development of methods, to specific applications and manual type publications. Probably the most widely recognized publication on coastal engineering in the world is our Technical Report No. 4 *Shore Protection, Planning and Design*. It is used internationally as a bible of methodology in shore protection. This report was first published in 1955. It has been updated with the latest shore protection practices three times since 1955. The last revision was in 1966. The report is being completely revised and expanded, and will be published under the title of *Shore Protection Manual* about the end of fiscal year 1973.

a. R and D in field of coastal engineering, covering coastal processes, winds, waves, tides, currents and materials as they apply to navigation, recreation, storm protection, erosion control, shore structures and offshore structures

b. Research on effects of engineering on coastal ecology

c. Publish information and data

d. Assist in planning and design of coastal works

e. Review studies, plans and specifications

f. Provide consultant services and specialized training

Figure 1: CERC mission.

1. Wind wave action in coastal waters
2. Shore processes
3. Long period waves and surges
4. Inlet and estuary dynamics
5. Coastal ecological studies
6. Coastal works evaluation
7. Development of design criteria
8. Offshore engineering works and effects
9. Environmental data collection

Figure 2: Coastal Engineering Research Program Elements.

CERC's research program is divided into nine basic program elements as shown in Figure 2. The first of these, wind wave action, covers the generation, propagation, transformation in shallow water, and breaking of wind waves. It also includes such other wave factors as wave run-up, over-topping, and forces.

The second element, shore processes, covers the reaction of the shore to forces imposed by waves, winds, and currents. Of prime importance is the movement of sedimentary materials, whether in an alongshore direction or in an on or offshore direction; the mechanisms of this movement; and the rates of movement. Included are direct erosion (recession) and accretion rates as well as alongshore transport rates. The generation of alongshore currents, and the overall near-shore circulation, which have a major effect on sediment transportation (as well as on such things as pollutant dispersion) are also studied in this element.

Element three, long period waves and surges, involves development of predictive methods for wind setup and storm surge, harbor surging and seiching, and effects of seismic and landslide generated waves both on our coasts and in reservoirs. There is a great deal of cooperative effort between our organization and the Weather Service in studying storm surge, although the Weather Service and the Corps have different missions. The Weather Service is primarily concerned with prediction of what will happen with a particular storm as it is occurring, while the Corps is primarily interested in determination of frequencies and elements of design storms.

Element four, inlet and estuary dynamics, is pointed at determining the mechanics of flow through inlets and in estuaries, and the effects of these on sediment transportation, shoaling of navigation channels, and shoreline changes.

Program element five, coastal ecological studies, has as its objective the development of a better capability for predicting quantitatively the effects of engineering activities on coastal ecosystems, and developing techniques for enhancing benefits and mitigating damages. This area heavily involves ecological engineering, that is, the use of natural biota to aid in engineering projects. We are presently working with vegetation for stabilization of shores, banks, and such things as dredge spoil, and in the development of artificial wetlands and marshes. Other work involves studies of ecological effects of using offshore sources of sand for beach fills.

Element six, coastal works evaluation, is the study of completed engineering projects over a period of time to evaluate their effectiveness and efficiency.

Element seven, development of design criteria, ties all of the other eight program elements together by taking the results of the research and putting them into a form suitable for use by engineers, planners and others for direct application to problem solution. It is within this element, for example, that the content of our *Shore Protection Manual* is produced.

Element eight, offshore engineering, is pointed at the improvement of the Corps' ability to design, construct, and determine effects (in this case on the physical processes) of offshore engineering works.

The last program element, environmental data collection, involves the procurement and development of data on environmental factors related to shore processes and design of coastal structures and projects. In many cases the data are obtained by other agencies of the federal government, but need translation into a form suitable for engineering usage. In other cases, the data are available only through the operations of the Corps. Of particular importance recently has been the collection of data on offshore sources of sand suitable for beach and shore nourishment. This latter is a program which is to be expanded into the Great Lakes area.

Much of the research carried out under these program elements is applicable to the Great Lakes shores as well as to the open coast or estuarine shores of the rest of the United States. Many of the techniques developed, and much of the knowledge obtained, has fed directly into planning and design of specific Great Lakes projects as well as those on the rest of our coasts. Consequently, it is exceedingly difficult to present a "Great Lakes Program" as distinct from the overall program of coastal engineering research.

Nevertheless, we do have underway certain studies which are pointed specifically at immediate Great Lakes problems, some of which are somewhat different from projects applicable to all coastal areas. One of these involves the effect of long-term lake level changes on shore erosion, and on the development of coastal features (such as the longshore bar system). We have been obtaining data for the last one to two years under two separate projects which should over a period of time define the change in rate of erosion as related to lake level conditions. Part of this work is being done through contract with Western Michigan University, and part through a cooperative arrangement with the State of Michigan and its Department of Natural Resources using park rangers. The former obtains periodic repetitive profiles at 17 locations covering the entire east coast of Lake Michigan. The latter project involves obtaining a certain amount of visually observed wave data and other littoral environmental observations at 21 additional sites. Studies, particularly in the Pentwater, Michigan, area, have been carried out on the type and rate of change of shore and nearshore characteristics, and the effect of harbor entrances and associated currents on sedimentation processes in the harbor area. Of particular importance in these studies has been the development and movement of the bar system. Evaluation of effectiveness and maintenance requirements of some coastal projects is underway, such as the beach restoration and nourishment and groins at Presque Isle, Pennsylvania, and the determination of littoral processes which predominate along a 37 mile length of shoreline on the southeast portion of Lake Michigan and include the recent navigation improvements at Burns Harbor, Indiana.

Among the more important studies which have been completed in the past are the collection of wave pressure data on a vertical caisson breakwater at Lorain, Ohio, and the determination of wave climate statistics throughout the five Lakes by hindcast methods from meteorological charts. A summary of this wave data for one location on Lake Michigan is shown in Figure 3. These data are of essential importance to the design of projects and engineering works on the Lake coasts. In addition, they can be used together with long-term predicted water level changes in the Lakes provided by the Lake Survey Center to obtain an estimate of damage potential over a long-term period. Methodology for increasing the accuracy of such estimates, and decreasing the period of effective time for which they must be made, is badly needed for problems such as we see today.

In looking at the Corps' program of research in the Great Lakes, I should point out that until 1970 the Lake Survey District of the Corps of Engineers had a major responsibility for the Corps in carrying out R&D efforts in the coastal field pointed specifically at Great Lakes problems. In 1970 this organization was transferred to the National Oceanic and Atmospheric Administration, becoming the Lake Survey Center. That portion of its mission dealing with research on shore processes, and the effects of various applied forces (such as waves and currents) and of engineering structures on the shore and coastal area was transferred to CERC. That part of its mission pertaining to the physical characteristics of water motion *per se*, that is, the determination of waves and currents in the Great Lakes, their generation and distribution in time and space, was transferred from the Corps of Engineers to the Lake Survey Center. A need for coordination of programs certainly exists here. This coordination is being effected in many ways. For example, the Lake Survey Center provides and maintains the wave gage for our project evaluation work being carried out at Burns Harbor, Indiana.

In summary, the Coastal Engineering Research Center has an ongoing program of research in coastal engineering of national application, of which many portions apply directly to Great Lakes problems. In addition, there are some projects having specific primary application to Great Lakes problems (such as high lake levels). Cooperation is sought, and maintained, with others working in complementary fields.

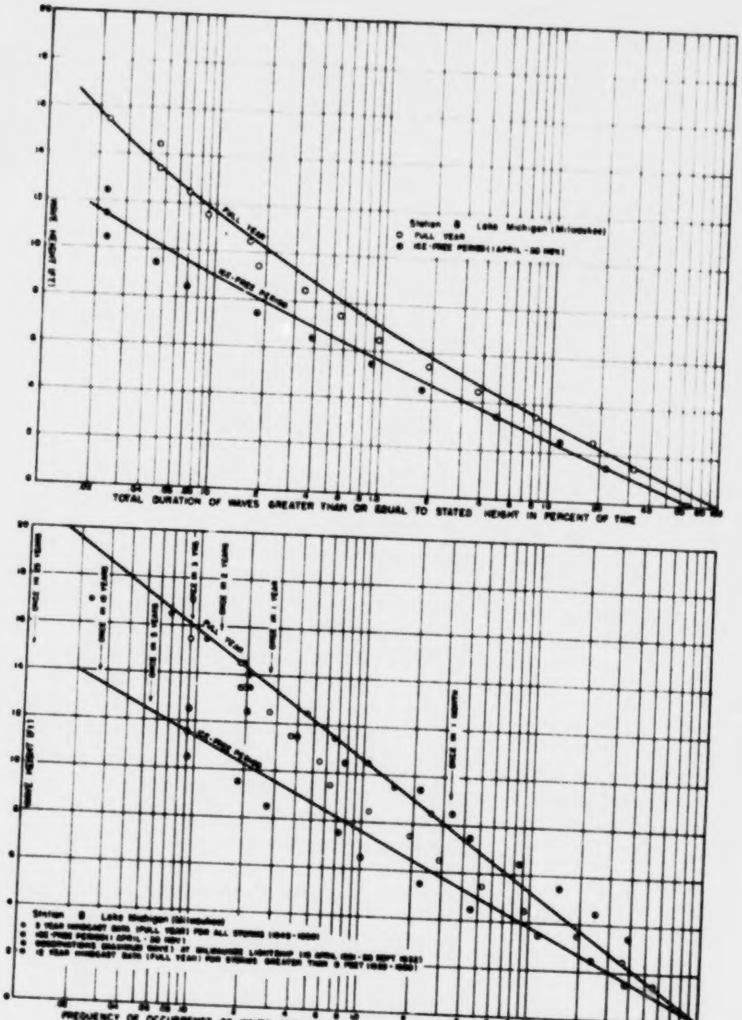

Figure 3: Sample of wave climate obtained by hindcasting from meteorological charts.

Engineering and Research to Support the Corps' Mission in the Great Lakes

F. R. Brown, Technical Director, Waterways Experiment Station, United States Army Corps of Engineers

ABSTRACT

The Waterways Experiment Station, an agency of the Army Corps of Engineers, operates directly under the Office of the Chief of Engineers, Washington, D.C. It has for over forty years served the districts and divisions of the Corps of Engineers as well as many other government and private agencies in the solution of hydraulic, soils, concrete, environmental, and related problems on a cost reimbursable basis.

Engineering and research in the Great Lakes area are accomplished under the sponsorship of the North Central Division, represented by Major General Ernest Graves, Division Engineer, or the districts which make up that division. Some work also is accomplished for local governmental or private agencies upon approval of the Office, Chief of Engineers, when such work relates directly to the Corps of Engineers mission.

Current engineering and research efforts are concerned with the development of efficient and economical small boat harbors located throughout the Great Lakes, improvement of navigation on the St. Clair and St. Lawrence Rivers, effects of cooling water discharge from nuclear and conventional steam plants, improved dredge spoil practices for more efficient utilization of dredged material to protect and enhance the environment, and the effect of offshore construction on mass circulation patterns. More specifically, projects concern the development of the Hamlin Beach Harbor on Lake Ontario, improvement of navigation in the Cornwall Reach of the St. Lawrence River, and the determination of the effect on adjacent shorelines of the construction of a large offshore jetport in Lake Erie. The latter work is being conducted for the Lake Erie Regional Transportation Authority and is financed in part by a Federal Aviation Administration grant and local funds. The dredge spoil disposal study is a Corps-wide study and is one of the highest priority projects under way.

Future engineering and research to be accomplished at the Waterways Experiment Station within the next few years involve Ludington Harbor on Lake Michigan, Little Lake Harbor on Lake Superior, and Cattaraugus Creek which discharges into Lake Erie.

* * *

PAST ENGINEERING AND RESEARCH EFFORTS
GREAT LAKES

Grand Marais Harbor
Duluth Harbor
Silver Bay Harbor
Taconite Harbor
Indiana Harbor
Port Washington
Gary Harbor
Agate Bay Harbor
New Poe Lock
Lorain Harbor
Buffalo Harbor
Conneaut Harbor
Vermilion Harbor
Oswego Harbor
Niagara Falls
St. Lawrence Seaway
Eisenhower Lock
Lake Erie–Lake Ontario Waterway

Figure 1.

CURRENT ENGINEERING AND RESEARCH EFFORTS
GREAT LAKES

SPONSORED BY CORPS OF ENGINEERS

- Model Study of Submerged Sills, St. Clair River
- Hamlin Beach Harbor, N. Y.
- Current Velocity System for Duluth Ship Canal
- Test Cores, Eisenhower Lock
- Disposal of Dredge Spoil

OTHERS

- Proposed Lake Erie Jet Port
- Cornwall Reach of the St. Lawrence River

Figure 2.

PAST RESEARCH

Past engineering and research efforts of the Waterways Experiment Station in the Great Lakes area are shown in Figure 1. To be noted is the fact that quite a number of studies have been conducted on all of the Lakes of the Great Lakes Complex. Attention is invited particularly to Taconite Harbor which is a study made for and financed by the Erie Mining Company. Another project is Indiana Harbor wherein a series of studies sponsored by Inland Steel Company and Youngstown Sheet and Tube Company were made to insure that the harbor would be satisfactory for wave protection. For the most part, however, the studies listed in Figure 1 were conducted for the numerous districts which make up the North Central Division and were financed by them as parts of a broader study to improve conditions on the Great Lakes. All of the studies were concerned with hydraulic problems, usually waves and currents except for Eisenhower Lock. The problems with the concrete at Eisenhower Lock are common knowledge and will not be discussed.

CURRENT EFFORTS

Current research and engineering efforts of the Waterways Experiment Station in direct support of Great Lakes research are shown in Figure 2. Four studies are sponsored by the Corps of Engineers and two by outside agencies. Space will permit only a few comments about each.

Effects of Submerged Sills in the St. Clair River Sponsored by the Detroit District

A final report of these studies was issued in August, 1972. The St. Clair River is a vital link in the Great Lakes inland navigation system in north-central United States. Low lake levels experienced in Lake Huron during the early 1960's had a significant detrimental economic impact on the area. In order to increase the water level in Lake Huron, plans for using submerged sills at the head of St. Clair River were proposed. Because of the impossibility of determining by analytical means the effect of these sills on water levels in the Lake and on navigation in the vicinity of the sills, a fixed bed, 1-to-60 scale model (Figure 3), was constructed. It reproduced approximately 2.8 miles of the St. Clair River and a small section of the lower end of Lake Huron. The results of the tests indicated that with the sill arrangements developed, water levels in Lake Huron could be raised 0.75 foot if desirable without adversely affecting navigation conditions. The sills developed also would reduce the size of eddies along the Canadian shore and the tendency for shoaling in that area. Figure 4 shows one of the radio-controlled bulk carriers which were used in the model to insure that navigation could pass over the sills of the St. Clair River without difficulty.

Model of Hamlin Beach Harbor

A 1-to-64 scale model of Hamlin Beach (Figure 5) was constructed to determine the optimum design and orientation of protective structures for the entrance to a proposed small boat harbor on Lake Ontario. The reduction of incident wave heights to acceptable levels in the navigation channel and harbor area at minimum cost was of particular interest. Model construction was completed in March of 1972 and testing has been conducted on a part-time

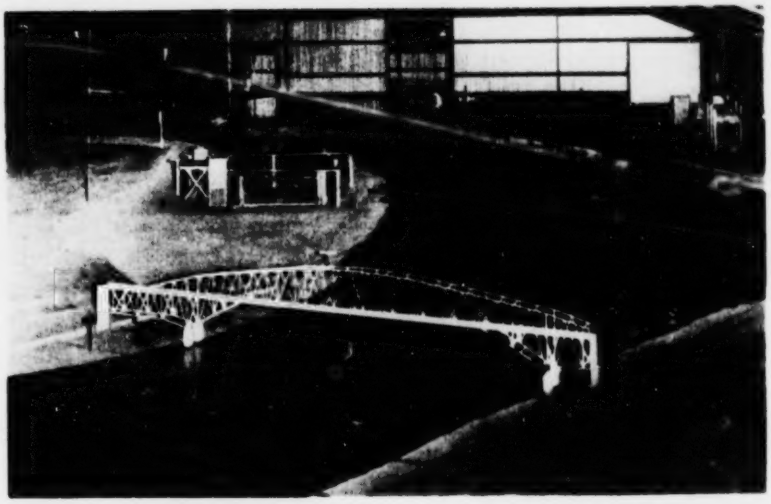

Figure 3.

basis since that time. The model demonstrated that the original proposed plan of improvement meets the desired wave-height criteria inside the harbor (less than or equal to 0.5 foot). Modifications to the breakwater plan are now being made to determine the shortest length of breakwaters which will still provide the desired protection. Every foot of breakwater that can be eliminated saves an appreciable amount of money.

Current Velocity System

To provide the Duluth Area Office of the St. Paul District with modern and more accurate instrumentation to record and indicate current speeds and directions in Duluth Ship Channel and Superior Entry, the Waterways Experiment Station is designing a new system. Such a system will be designed around commercially available acoustic pulsed doppler equipment. Design work has just been initiated, and it is anticipated that the equipment will be ready for installation within the next year.

Concrete Cores

There is very little to report on the test blocks in Eisenhower Lock. These are concrete specimens which have been submerged through the entire summer months and are just now being lifted up on top of the lock wall where they will be subjected to the freezing action of the oncoming winter. Similar research is also underway on several sets of concrete cores from the new second lock at Sault Sainte Marie. The purpose of this work is to improve current practices and techniques for constructing concrete structures in cold climates.

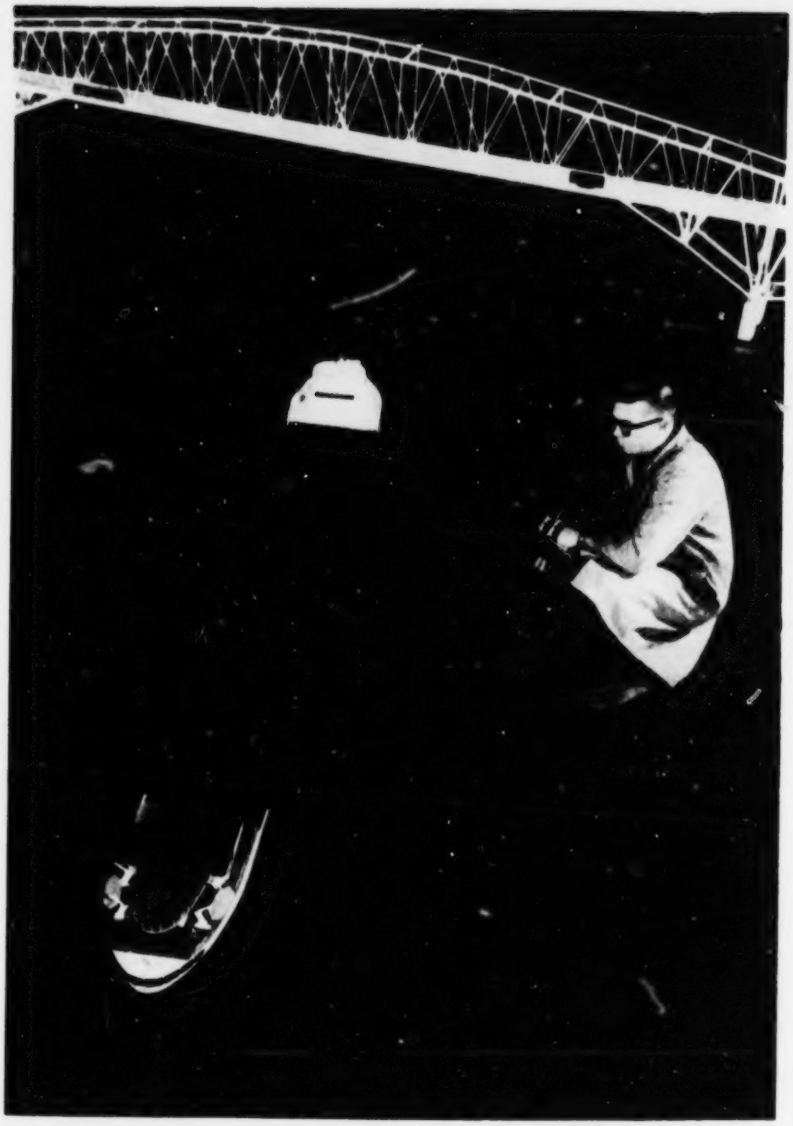

Figure 4.

Figure 5.

Dredge Spoil Disposal

One of the most important studies in the Great Lakes area concerns the disposal of dredge spoil. This is probably one of the most difficult problems confronting the Corps of Engineers today. Everyone wants his harbor and channel dredged to depths which will accommodate shipping, but few will assist with the disposal of the material dredged. In the Great Lakes, open water

DREDGE SPOIL DISPOSAL STUDY

PHASE I - PROBLEM DEFINITION AND ASSESSMENT

PHASE II - DEVELOPMENT OF RESEARCH PROGRAM

PHASE III - RESEARCH ACCOMPLISHMENT

PHASE IV - PROTOTYPE TESTS

Figure 6.

DREDGE SPOIL DISPOSAL STUDY
STATUS

Authorized -- **Dec 71**

Draft Report ------------------------------------ **June 72**

Reviews:

- **Divisions and Districts**
- **Smithsonian Advisory Committee**
- **EPA**
- **CEQ, NSF, NOAA, Interior**

Detailed Research Plan

- **First year effort** ---------------------------- **Oct 72**
- **Complete plan** ------------------------------ **Jan 73**

OMB Submission - 30 Nov 72

Start Research - After OMB Approval

Figure 7.

disposal has been banned for the most part, and all spoil disposal must be made on land or in contained disposal areas. However, such sites for disposal of dredge spoil are extremely difficult to acquire and, when acquired, are often expensive. No one really has sufficient knowledge as to the nature of problems or whether any in fact exist. Accordingly, a dredge spoil research program was authorized by the Rivers and Harbors Act of 1970, which calls for a comprehensive program of research, study, and experimentation. Such a study shall include, but not be limited to, investigations of the characteristics of dredge spoil and alternative methods of its disposal. The study was broken into four phases as shown in Figure 6.

RECOMMENDED RESEARCH PROGRAM

1. Environmental Impacts and Aspects of Open Water Disposal
2. Environmental Impacts and Aspects of Land Disposal
3. New Spoil Disposal Concepts
4. Productive Uses of Spoil
5. Spoil Area Reuse and Multiple Utilization
6. Spoil Treatment Techniques and Equipment
7. Dredging/Disposal Equipment and Techniques

Figure 8.

The current status of the work at the moment is shown in Figure 7. This is about a five-year program. Phases 1 and 2 are practically completed, and last week a meeting was held with the Office of Management and Budget to discuss the financing of the work during the current and ongoing fiscal years. Total expenditures overall are anticipated to be in the range of $30,000,000. It is desirable to point out, however, that this expenditure is for work across the entire United States and not just for the Great Lakes area alone.

The amount of dredging in the Great Lakes area accounts for only about 3 percent of the total volume accomplished by the Corps of Engineers and others. Figure 8 presents a resumé of the research program proposed in broad terms. A detailed research program has been developed for the first year's efforts, and its accomplishment will tax to the utmost the resources of all the districts and divisions of the Corps of Engineers, private contractors, universities, and many others who would have input in the study. The Waterways Experiment Station cannot do the job by itself.

Lake Erie Jetport Project

There are two other projects which fall within the Corps of Engineers' interest but are being sponsored by other agencies. The first of these concerns the Lake Erie Jetport Project. An initial study is being made by the Waterways Experiment Station to determine the number and types of hydraulic models required to check the engineering feasibility of the proposed project. The proposed jetport is about three miles wide and extends eight miles out into Lake Erie at Cleveland (Figure 9). The work is being sponsored by the Lake Erie Regional Transport Authority funded with an FAA grant in the amount of $800,000 and local matching funds of $400,000. Work at the

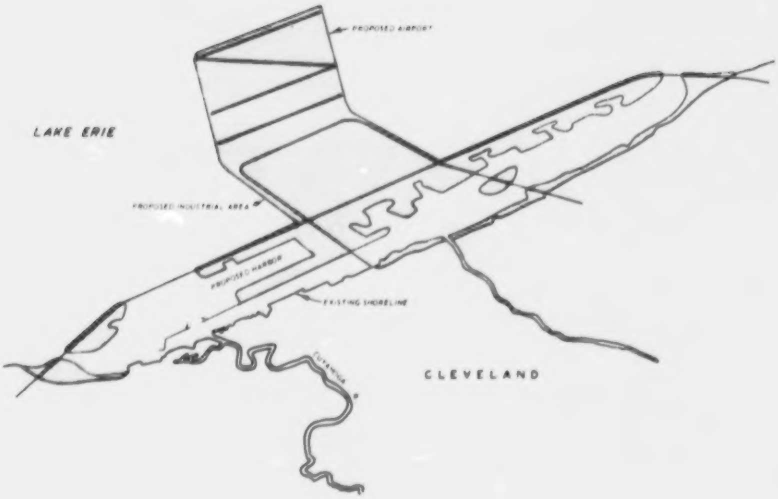

Figure 9.

Experiment Station is confined to studying the quantity and quality of available wind-wave, seiche tide, and mass circulation data for the Lake. Also being investigated are heights, periods, and frequency of occurrence of wind waves approaching the jetport from critical directions. From these studies, a determination will be made of the boundaries and boundary conditions for proposed hydraulic models. In all probability models of wave action, breakwater stability, and circulation will be required. It may also be necessary to study the effect of the new works on coastal erosion in the immediate area. The literature surveys and analytical studies will be completed by the end of the calendar year 1973.

Cornwall Reach of the St. Lawrence River

The last study which constitutes the current engineering research efforts of the Waterways Experiment Station is sponsored by the St. Lawrence Seaway Development Corporation and concerns the improvement and realignment of currents in the Cornwall Reach of the St. Lawrence River. A model of the fixed-bed type constructed to an undistorted scale of 1-to-120 reproduces the south channel of the St. Lawrence River from Snell Lock to the bend downstream of the International Bridge, Polly's Gut, a short reach of the channel downstream of the powerhouse, the mouth of the Grass River, and the adjacent overbank areas (Figure 10). The purpose of the model is to investigate navigation conditions in the south channel, particularly for upbound ships as they approach the lower guide wall at Snell Lock. Work at present is concerned with the adjustment of flow distribution to reproduce existing conditions.

Figure 10.

GENERAL

Although the comments in this paper have been confined to research in direct support of efforts to improve the Great Lakes, there are many research projects of a general nature being conducted at the Waterways Experiment Station under the sponsorship of the Office, Chief of Engineers. The results of those studies are applied to the Great Lakes as well as other areas of the country. Included are studies on the thermal effects of heated discharges from nuclear and conventional power plants, waste water management, sedimentation, and computer simulation models.

FUTURE RESEARCH

Future work of the Corps of Engineers now scheduled for accomplishment at the Waterways Experiment Station is shown in Figure 11. Three studies are indicated in addition to the Dredge Spoil Study mentioned earlier. The proposed study of Ludington Harbor located on the eastern shore of Lake Michigan is to evaluate wave conditions at the harbor subsequent to a widening and deepening of the approach channel. A model scale of 1-to-100 has been proposed. It is anticipated that the study will commence about spring of next year. Another study scheduled for about the same time concerns the junction of Cattaraugus Creek with Lake Erie. The purpose of this study will be to evaluate the currents and waves and the possible effects on small boat craft. A study of entrance channel shoaling caused by a

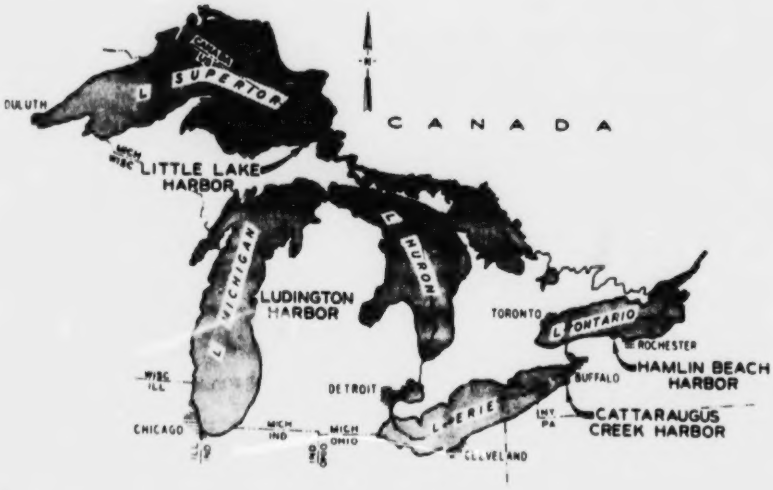
N
CANADA
DULUTH
L SUPERIOR
MICH
WISC
LITTLE LAKE HARBOR
L MICHIGAN
LUDINGTON HARBOR
L HURON
TORONTO
L ONTARIO
ROCHESTER
HAMLIN BEACH HARBOR
BUFFALO
DETROIT
L ERIE
WISC
ILL
CHICAGO
MICH
IND
MICH
OHIO
N.Y.
PA
CATTARAUGUS CREEK HARBOR
CLEVELAND

Figure 11.

combination of seiching action and littoral currents resulting from storm conditions has been proposed for the Little Lake Harbor located in Lake Superior. The Detroit District is in the process of reevaluating the cause of the problem at the moment.

CONCLUDING REMARKS

From my preceding remarks one might conclude that the Waterways Experiment Station is concerned only with engineering and research to improve the navigation and mooring conditions in harbors on the Great Lakes. While this is partially true, the environmental aspects of problems are not ignored. Where a particular project is concerned, such as Hamlin Beach, the Buffalo District and the North Central Division have the responsibility for determining the environmental impact. The Waterways Experiment Station can support their efforts in case such help is required. For example, although not part of Great Lakes research, the Waterways Experiment Station is currently working with the North Central Division on the environmental effects of providing a 12-foot draft channel and a duplicate lock system on the Illinois Waterways. Personnel with advanced knowledge in such disciplines as ecology, marine biology, limnology, botany, chemistry, geology and sanitary engineering operate as a multidisciplinary team in the solution of such problems. The largest and most concentrated effort on environmental effects will concern the dredge spoil study. In the Great Lakes area engineering and research must be accomplished to improve navigation and harbor conditions for economic benefits, yet such benefits must not impair the environment. If such impairment is considered necessary, the consequences should be defined.

Application of Ice Engineering and Research to Great Lakes Problems

*Dean R. Freitag, Technical Director Cold Regions
Research and Engineering Laboratory,
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ABSTRACT

The Cold Regions Research and Engineering Laboratory (CRREL) conducts research, studies, and investigations on physical phenomena associated with temperatures near or below the freezing point of water. Although in the past much of the research has been sponsored by the military, the breadth of the research program has been and remains quite large. There are studies of snow control and removal, ice engineering, fog dispersal, frost effects in soil, interpretation of satellite imagery and forecasting dates of freeze up, ice thickness, etc. A number of basic science studies support this work, for example, research on basic crystallography of ice, paleoclimatology, geophysics, and the ecology of the tundra biome.

Much of the expertise acquired by CRREL has direct application to current problems of the Great Lakes Region. This has recently been recognized by the Corps of Engineers, and the laboratory is active in the study of the extension of the navigation season on the Great Lakes. The specific studies being pursued on that project are:

Measurement of forces on ice booms
Measurement of ice forces on waterfront structures
Measurement of horizontal and vertical ice forces on piling

Other research directly involving the Great Lakes includes a study of pollution patterns from satellite-based imagery and assistance in the development of bubble systems for ice control.

* * *

The Cold Regions Research and Engineering Laboratory of the Corps of Engineers has the responsibility for conducting and monitoring scientific and technological programs in the cold regions of the world (Figure 1). Over the years a background of experience has been acquired from research and engineering efforts conducted in the northern U.S., Alaska, Canada, Greenland, and Antarctica. The programs include both applied and basic research studies. The basic research has included glaciological and climatological studies, investigation of the basic properties of snow, frozen ground,

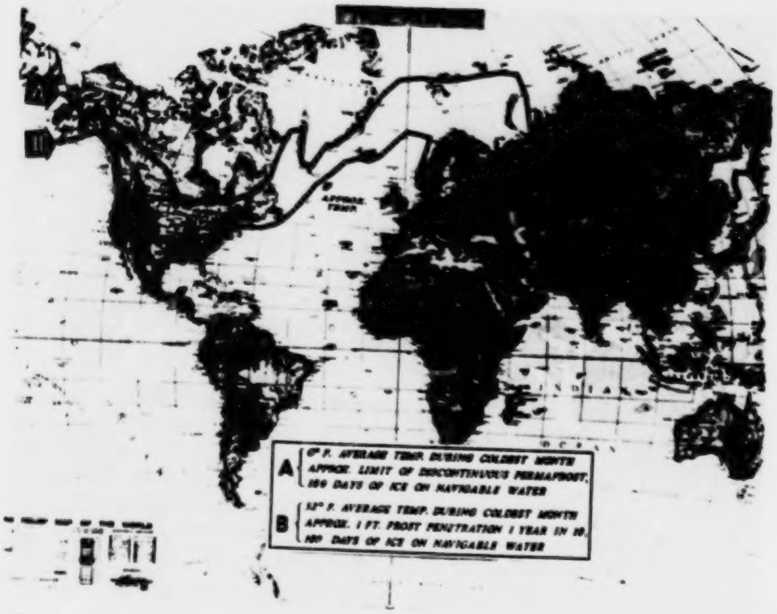
A
B
AVERAGE TEMP.
A { 0° F. AVERAGE TEMP. DURING COLDEST MONTH
APPROX. LIMIT OF DISCONTINUOUS PERMAFROST.
100 DAYS OF ICE ON NAVIGABLE WATER
B { 32° F. AVERAGE TEMP. DURING COLDEST MONTH
APPROX. 1 FT. FROST PENETRATION 1 YEAR IN 10.
100 DAYS OF ICE ON NAVIGABLE WATER

Figure 1: Delineation of cold regions.

freshwater ice and sea ice, and basic geomorphological, botanical, and ecological studies.

These programs in part support the more applied studies which include investigation and development of design criteria for facilities in areas affected by seasonal frost and those where the ground remains permanently frozen. These studies include foundation studies, development of improved procedures for operating and maintaining facilities, development of adequate water supply and sewage disposal systems, site selection and sub-surface exploration, trafficability of various surfaces, construction of expedient facilities and excavation of frozen ground. These are just some of the major areas of research that have received considerable attention.

The present workforce of the laboratory is composed of about 242 civilians and 51 military personnel. There is a 125-man scientific and engineering staff that is well diversified, permitting overall technical coverage of the problems common to the cold environments. One of every five professionals holds a Ph.D. and of the remainder almost one-half have Master degrees. A large part of the present laboratory, constructed in 1961, is devoted to modern testing facilities, including some 24 cold rooms. The results of the investigations conducted by the laboratory are embodied in a series of well over 1000 technical and research reports.

The bulk of CRREL's work is oriented toward solution of Corps of Engineers and Army problems, but a significant percentage will be reimbursable work for such agencies as the National Science Foundation and National Aeronautics and Space Administration.

This year CRREL is conducting four studies specifically dealing with the Great Lakes. They are sponsored under two different research programs. Three of the studies are part of the Great Lakes-St. Lawrence Seaway Navigation Season Extension Demonstration Programs. They are: (1) forces on ice booms, (2) ice forces on structures, and (3) vertical and horizontal forces on piling. This work is expected to continue through fiscal year 1974.

The other study does not involve ice nor ice engineering directly at this time. It is part of Earth Resources Technology Satellite program being conducted as part of the Civil Works program of the Corps of Engineers. The title of this study is "Aquatic Pollution of the Great Lakes." Work is in progress this year and it is expected to continue through fiscal year 1974. In this study it is proposed to relate land use type and intensity to existing aquatic pollution patterns. In this case the patterns are specific to Lakes Michigan and Superior. This study relies on the analysis of high altitude and satellite infrared imagery and related remote sensing techniques.

The color IR data has proven to have the greatest utility for the investigation so far. It is superior for most aspects of land use mapping and provides high contrast detail for many aquatic pollution types (Figure 2). The natural color emulsion does provide valuable supplementary information, however, in a number of feature types where color is an important interpretation guide and to identify cases where aquatic patterns seen on the color IR may actually be bottom or shoaling patterns rather than suspended material.

On a large scale, the relationship between land use type and intensity is direct. Forested areas, agriculture, urban, and industrial areas can be broadly categorized as having a certain potential for types and quantities of pollution. As major land use patterns change, types and levels of pollution of adjacent water bodies can also be expected to change. The evaluation of the status quo can be accomplished in a uniform manner over a large regional area by interpretation and mapping of patterns detectable by remote sensing techniques. This will provide a valuable tool for the estimation of rates of change and the planning of more effective utilization of terrestrial and aquatic resources.

For example, stream sedimentation can be considered as a form of pollution. In addition to natural sources, sedimentation amounts are influenced by land use practices. On the Wisconsin shoreline of Lake Michigan, there are no natural harbors. All ports along this coast are dredged-out stream entrances into the Lake. They are protected by breakwaters from wave attack and longshore currents. The sediment load of these streams determines to a large extent the amount of material that must be removed by dredging. A goal of the initial phase of this research is to determine to what extent stream sediment loads are influenced by land use characteristics within a watershed and whether a model could be constructed to predict the effect of changing land use patterns in the future. This information would be of value to determine the magnitude of potential harbor maintenance and could help resolve questions about the feasibility of new harbors.

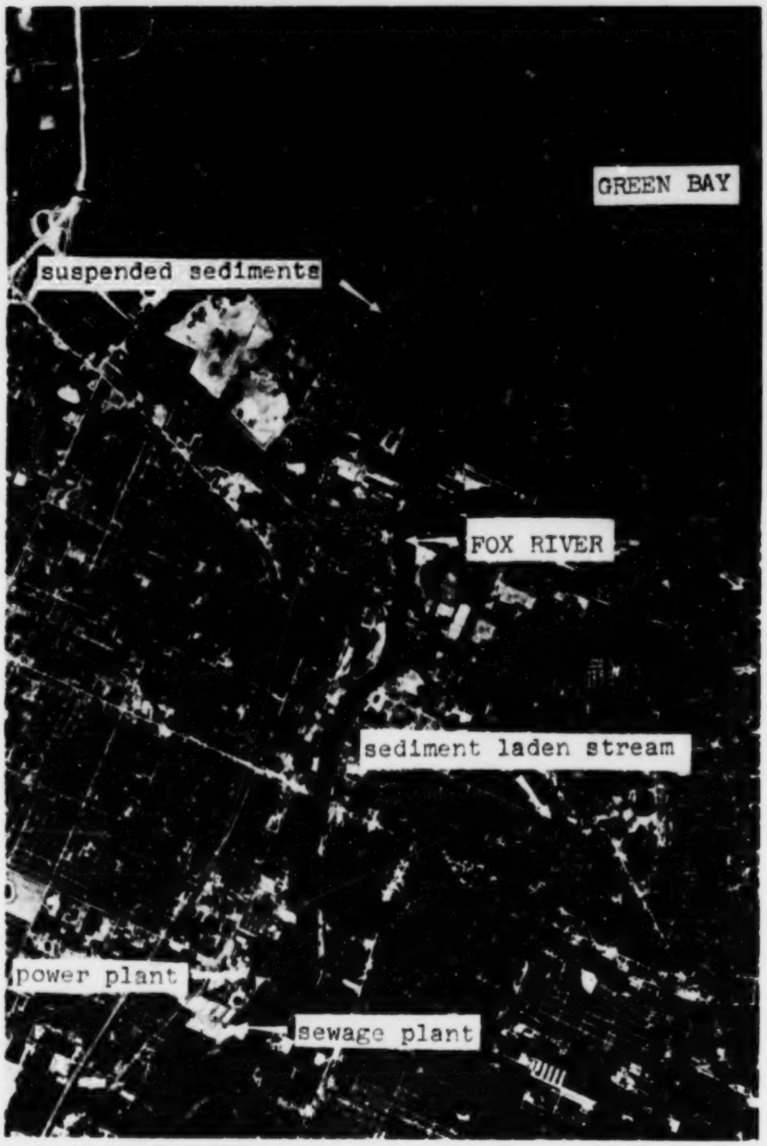
GREEN BAY
suspended sediments
FOX RIVER
sediment laden stream
power plant
sewage plant

Figure 2: Sediment patterns in the vicinity of Green Bay. Light tone of municipal effluents indicated in the Fox River is probably due to remixing of suspended sediments of paper mill discharges upstream. Larger sediment patterns in Green Bay can be attributed to both natural and industrial causes. This is a black and white rendition of the original color IR, scale 1:60,000.

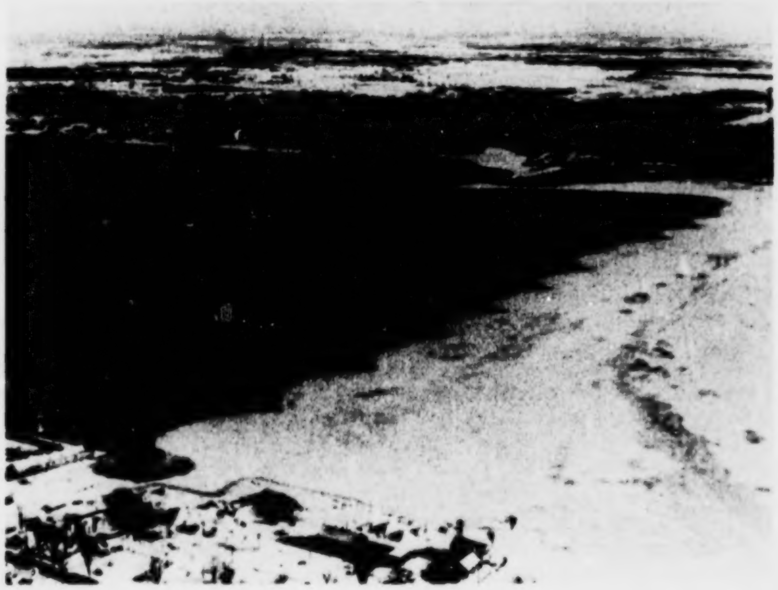

Figure 3: Ice booms such as this one on the St. Lawrence Seaway are used to stabilize the ice cover and prevent conditions of loose, moving ice which may cause ice jams and ingestion of ice by intakes of power plants. The ice booms are constructed of steel cables and wooden logs. The forces of ice on these booms are a current area of investigation by USACRREL.

The work being done under the navigation season extension project involves primarily CRREL's expertise in the fields of ice engineering and associated instrumentation.

Ice booms are used on rivers to retain the ice and facilitate the development of a secure ice cover (Figure 3). If the ice is not held in place major problems can result from ice jams, ice in power intakes, and ice destruction of structures and shorelines. Winter navigation will open a channel through this ice cover. Additional ice booms and anchoring methods incorporating new design concepts are needed to stabilize ice on both sides of the channel. Because little is known of the actual forces on such structures, the initial work has been directed toward obtaining these measurements. The forces on the boom, the ice thickness, wind, and water velocities will be monitored throughout the winter and spring.

The forces exerted by ice on shorelines and harbor structures can achieve major proportions (Figure 4). The docks, piers, and other facilities currently in place have never had strong winter ice pushed against them by maneuvering vessels. Neither have there been frequent large accumulations of broken ice to

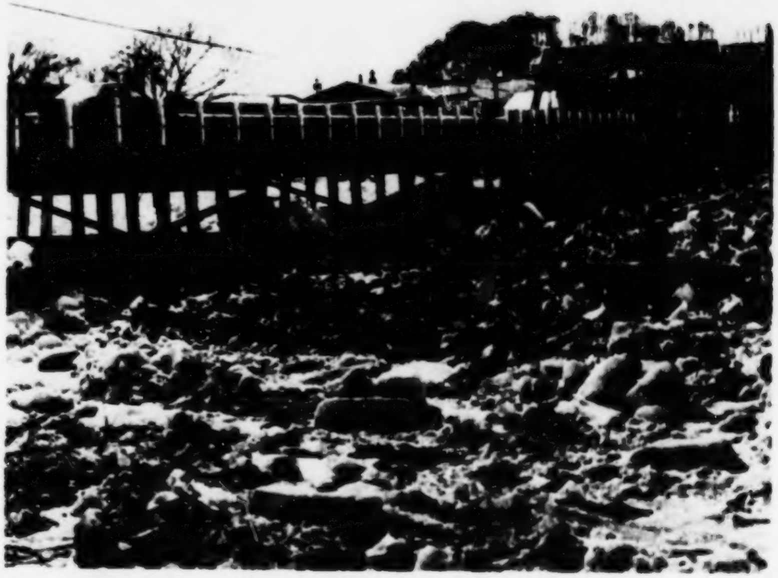

Figure 4: Ice jams like this one cause tremendous forces to be exerted on bridge piers. In many cases these forces of ice have been underestimated in bridge design, resulting in collapse of the bridge.

be wind-driven into shorelines and facilities. There are few data on the actual forces an exposed structure must withstand. CRREL's study is intended to begin to provide some of these answers. Force cells are being attached to existing structures and ice deliberately forced against them and appropriate measurements made. The work has begun with the installation of instrumentation on a Coast Guard navigation structure.

The third and final study involves forces on piling. Most waterfront structures are founded on piling. Where these pilings extend through the water level they are subjected to unusual forces by ice action. Horizontal forces are created by ice masses pushed against the shore by wind or maneuvering of ships. Vertical forces are encountered when the pile is gripped at the water line by strong thick ice and then the level of the water body is either raised or lowered (Figure 5). Simple wave action can create cyclical vertical forces in the same manner. The study is planned to obtain some measurements of the forces involved. Measurements will eventually be made on actual structures, but because such measurements are not easily made, a great deal of reliance will be placed on laboratory studies. Ice will be formed in the cold pit at CRREL under controlled conditions. Piling of various shapes and sizes will be forced horizontally into the ice or caused to move vertically with respect to the ice surface.

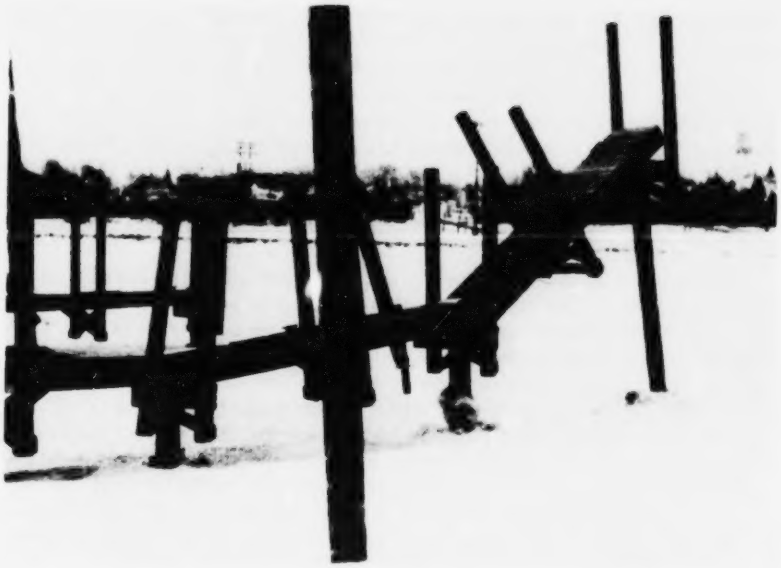

Figure 5: Some piles of this small boat dock have been lifted out of the river bottom by ice. Changes in water level or wave action cause the ice cover to change elevation, lifting the piling.

There are a number of other ice engineering studies of importance to the Great Lakes that could draw upon CRREL's capabilities. One area involves the suppression of ice formation by thermal means. This can be done either by (a) use of air bubbler systems which serve to advect warm water from lower depths to the surface or (b) the introduction of warm water into the waterway with heat provided from some external sources. Bubbler systems are attractive because they utilize the natural thermal reserve of a water body while thermal effluents are attractive if an existing supply of warm water is available, as for example, the waste heat efflux from industrial processes or power plants.

CRREL personnel have had a great deal of experience with ice breaking problems. CRREL participated in 1968 in the Coast Guard full-scale ice breaking tests of the *Raritan* (110-ft. buoy tender) and the evaluation tests of the *Alexbow*. Again in 1971 CRREL assisted the Coast Guard in the ice resistance tests of the cutter *Mackinaw*.

In 1972 CRREL conducted ice resistance tests on the Upper Mississippi River aboard the *MV Renee G*, a typical inland waterways towboat pushing six loaded barges. With the barges and boat all interconnected this was in fact one ship 741 x 70 ft, somewhat larger than present ore boats, but not as deep. In these various tests the power required to break ice of varying thickness was measured and the continuous speed the ships of different hull shape could maintain in these conditions was determined. Ice resistance was found to be a major factor influencing the success of operations in ice filled water.

To date nearly all of the experimental work on ice mechanics has been accomplished either in rather small cold rooms or in the field. On one hand, severe limitations are imposed on modelling techniques by the small and restricted facilities of the cold rooms. On the other hand, working in the field at full scale is costly in terms of time, personnel, and logistics and additionally is hampered by natural variations in test conditions. In order to better evaluate ice forces, the Corps of Engineers is evaluating plans for an ice engineering facility.

No such facility now exists in the U.S. and there are only a handful in the world. Basically, it will consist of a deep basin, a broad shallow basin and a flume, all refrigerated of course, to develop the ice conditions needed for a particular study. Among the topics that could then be studied in depth the year around are ice forces on structures, formation of pressure ridges in ice sheets, ice suppression systems, vessel design requirements, ice modelling techniques, mechanics of formation of ice covers, frazil ice development, effects of wave action on ice sheets, ice jams, ice clogging of intakes and many more. The importance of these topics to waterborne commerce, flood control and the environment is great. If such a facility were now in existence the solution of many of the Great Lakes ice-related problems would be nearer.

Great Lakes Programs of the Department of Commerce

David H. Wallace, Associate Administrator for Marine Resources, National Oceanic and Atmospheric Administration, Department of Commerce

ABSTRACT

The Department of Commerce has two major agencies with research activities that relate to the Great Lakes, the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Maritime Administration (MARAD).

NOAA was organized, based on the recommendations of the Commission on Marine Science, Engineering and Resources, by the President in his Reorganization Plan No. 4.

The major components of NOAA, and some highlights of their Great Lakes activities are:

- National Marine Fisheries Service administers grants-in-aid for fisheries programs in cooperation with Great Lakes states.
- National Weather Service prepares and disseminates forecasts and warnings of weather hazards and floods.
- National Ocean Survey, which contains the Lake Survey Center, publishes navigational charts and hydrological and limnological information.
- Environmental Research Laboratories undertake weather modification programs relating to lake snowstorms, as well as oceanographic and atmospheric research.
- Environmental Data Service processes and disseminates Great Lakes climatological and oceanographic data.
- National Environmental Satellite Service obtains oceanographic and hydrologic information through the use of remote sensors on NOAA and NASA satellites.
- Office of Sea Grant provides grants to three Great Lakes universities for studies relating to the development and management of Great Lakes resources.

National Oceanic and Atmospheric Administration (NOAA) is the U.S. lead agency for International Field Year for the Great Lakes (IFYGL), a large multi-agency U.S.-Canadian field program that will characterize the limnology, hydrology, and meteorology of the Lake Ontario Basin.

The Maritime Administration, through its programs for improving navigation aids and ship design under ice conditions, facilitates Great Lakes transport and trade.

* * *

I am pleased to provide a brief overview of the marine efforts of the National Oceanic and Atmospheric Administration and the Maritime Administration (MARAD) of the Department of Commerce. These remarks are intended as a prelude to the detailed presentations that follow on the application of these efforts to the Great Lakes area.

The importance of this region, and the reason for the interests of the Department of Commerce here, are well known. This is one of the fastest growing areas of the United States. While the Basin represents only four percent of the nation's land area, it is home for fourteen percent of the population. Large deposits of iron ore are located to the northeast and northwest. The south provides the necessary coal. About half of our heavy industry is located in or near Great Lakes shores. Large water supplies, about one-fourth the nation's total, support major production and manufacturing activities. And our waterborne commerce is expected to nearly double by the year 2020. Lake problems requiring attention are thus numerous and include winter navigation, lake level and depth forecasts, the requirements for increased power supplies, water pollution, crowded recreational facilities, shore erosion, and flooding. NOAA and MARAD are addressing a number of these problems, both directly and indirectly.

Let me first review some of the activities being undertaken by NOAA, which was established in 1970 by the President through his Reorganization Plan No. 4. NOAA's Great Lakes programs are in pursuit of goals which are also our national goals. They are directed toward contributing to the exploration, development and conservation of our ocean resources, both living and non-living, toward contributing to the health, safety, and welfare of our people through the efficient use of the marine environment, and through the assessment of the effects of both conscious and inadvertent modification of the environmental processes and the exploitation of beneficial modification. Activities to meet these goals are supported through several national and regional programs which incorporate the Great Lakes Basin into their full scope. Examples of such activities are the National Meteorological Center and the National Severe Storm Forecast Center of the National Weather Service, the National Climatic Center and the National Oceanographic Data Center of the Environmental Data Service, the grant-in-aid program of the National Marine Fisheries Service, and the National Sea Grant Program which includes support of the institutional programs at the University of Wisconsin. Incidentally, the University of Wisconsin was recently given special recognition by the Secretary of Commerce as a Sea Grant College, the first on the Great Lakes. In addition, there are programs specifically directed to Great Lakes needs for environmental services and resource information, such as the work of the Lake Survey Center of the National Ocean Survey; hydrologic, marine, and weather forecast services of the National Weather Service; fishery management and services of the National Marine Fisheries Service; the weather modification programs of NOAA's Environmental Research Laboratories which include studies to develop and test the feasibility of modifying the snowfall and intensity of winter lake storms; the programs of the National Environmental Satellite Service in evaluating a variety of sensors for the measurement of parameters of special interest here, such as the characteristics and distribution of ice and snow in the Lakes and Basin; and of course, the International Field Year for the Great Lakes, a program being conducted in the U.S. in collaboration with Canada and led by NOAA. IFYGL is perhaps the most comprehensive study of the meteorology, ecology, circulation, water balance, and pollution conditions of the Great Lakes undertaken to date and will provide for us a basis for management decisions affecting navigation, hydropower, public water supplies, waste disposal, and navigation.

The Maritime Administration is also extremely active in a number of programs of interest to the Great Lakes. MARAD had its genesis with the U.S. Maritime Commission which was established in 1936. In 1950, the Commission evolved into MARAD and the Federal Maritime Commission.

In the broadest sense, the programs of MARAD are directed toward aiding in the development, promotion, operation, and maintenance of the U.S. merchant marine, toward improving the competitive position of our merchant marine through productivity gains in ship construction and ship operations. In supporting these national goals, MARAD's programs also contribute to the development of water-borne commerce in the Great Lakes.

With respect to our interests at this conference, I would like to mention briefly a few relevant programs being pursued by MARAD in maritime technology, ship development, and ship operations. In technology, MARAD is developing innovations through marine science and ship component development which can serve as the basis for advanced competitive ships and shipping systems in existing and new commodity markets. In ship development, its programs are directed toward reductions in ship building and operating costs such as automated ship operations and advanced crew skills, as well as increased productivity in ship construction. In ship operations, MARAD is studying means for maximizing cargo throughput at lowest cost and improving operational safety with attendant preservation of our ocean and coastal environment. Included are the development of shipboard equipment and systems to permit our ships to meet environmental standards for pollution abatement at the least cost; and, an area of increasing interest to us all, contributing to the growing federal activity in off-shore terminals through studies to determine the technical, economic, and operational feasibility of such marine terminals. Specifically with respect to the Great Lakes, MARAD is providing significant input to the major efforts of the Army Corps of Engineers and others in extending the winter navigation season. In this, its efforts are focused on the development of productive and efficient ice-transiting vessels and involve hull configurations, cargo and route analysis, improved navigation, and other factors affecting trade costs.

In closing, I would like to identify some of the future thrusts of NOAA and MARAD programs from which the Great Lakes Basin will benefit. Of course, we expect to continue many of our present development programs and public services, improving on these as necessary to meet the requirements of changing conditions and times.

Within NOAA, we will be examining the need for additional selected marine environmental programs in support of Great Lakes needs for services and management, in support of our own broad programs of national scope, and in support of other agencies such as the Environmental Protection Agency and the Army Corps of Engineers.

NOAA's programs for providing mapping, charting and weather services appear to be adequate presently. We will, however, be looking at the need for further developing the coupling between marine and atmospheric effects and their impact on the lakes and the littoral environment.

We will also be carefully examining, with the bordering states, our programs supporting commercial and sport fishing and their proper management.

Earlier, I mentioned the Sea Grant program. As you know, a significant part of this program has been its most effective Advisory Service, dedicated to the transfer of scientific research and technology development, to the dissemination of interpretation of laws, of new regulations, and to assisting small marine business in numerous administrative and operational problems to all classes of coastal zone residents—to industry and the individual business man, to the academic community, to the private citizen.

Building on this Sea Grant Advisory Service, NOAA has just established the National Marine Advisory Service which will coordinate all of NOAA's advisory services, not only those of Sea Grant, but also those of other NOAA components, such as the National Marine Fisheries Service, to provide the full scope of such services to the public.

In MARAD, support to the broad array of national needs such as those I mentioned is expected to continue. Of growing importance within those, however, will be efforts dealing with off-shore terminals and improvements in domestic shipping.

Finally, our future efforts, those of NOAA, MARAD, and other agencies, as well, will be significantly influenced by a number of new laws affecting the Nation's interests in marine affairs enacted by the 92nd Congress. Very important to all our coastal states, including those bordering the Great Lakes, is the Coastal Zone Management Act which provides for a federal-state partnership to preserve, protect, develop, restore and enhance the nation's coastal zone.

Within the Department of Commerce, NOAA is the responsible agency for implementing the provisions of this Act. We are in the beginning phases of this effort and have already held discussions with several states, as well as associations representing various regional government groups. I fully expect that the management plans which are developed through this partnership and prosecuted by the states will provide significant benefits to the preservation and effective utilization of the Great Lakes and the Great Lakes Basin.

Great Lakes Research Program

L. Bajorunas, Lake Survey Center
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ABSTRACT

The research program of the Lake Survey Center consists of data collection, investigations, and studies in the following five specific fields.

Water Motion

This type of research encompasses the systematic studies of waves, tides, surges, seiches, and currents in lakes and harbors. The various motions are studied as functions of the geometry of the basins, the mass and energy of the bodies, and the energy interchange at the boundaries. Mathematical models are derived or statistical relationships are developed.

Water Characteristics

Research in water characteristics involves collection, analysis, and interpretation of data pertaining or related to physical and chemical characteristics of the fresh water in the Great Lakes; definition of those water properties which may be utilized as indices; and development of systematic relationships of significant indices. Energy budgets and chemical budgets are developed to establish dynamic relationships of the environment and to explain evaporation, lake currents, and other physical variables. Plans also include installation of permanent monitor stations.

Limnogeology

This research is designed to obtain knowledge on the sedimentology of the Great Lakes lake bottom, and shoreline characteristics, including the effects on water quality, rates of littoral transport and shoreline changes, geologic history and the crustal movement in the Great Lakes region.

Lake Hydrology

This research analyzes data on hydrologic factors affecting the Great Lakes, such as inflow, outflow, precipitation, evaporation, ice cover, and snow

accumulation. Purpose of the studies is to develop or improve methods to forecast water supply, lake levels, and the formation, extent, and breakup of ice cover.

Limnologic Systems

The objectives of the limnologic systems studies are to develop process-response models to simulate the complex interrelationships that exist between the individual processes within the Great Lakes and their immediate environment. These models will provide the basis for optimum utilization of the water resources, stress and disaster predictions, and statistical analyses of random events.

* * *

INTRODUCTION

The research program on the Great Lakes was started by the U.S. Army Corps of Engineers in 1962. In May 1966 the research component of the Lake Survey District of the Corps was designated "Great Lakes Research Center." In October 1970 the Research Center was transferred with other Lake Survey Center programs to the National Oceanic and Atmospheric Administration and subsequently designated as the Limnology Division.

Objectives of the research are:

(1) To define the present conditions of the Lakes.
(2) To determine and quantify the complex interrelationships of the natural processes occurring in the water bodies and at the air-water and water-sediment interfaces.
(3) To forecast the natural trends, the effects of cultural input, and the results of structural changes.

The present research program is divided into five fields:

Water motion
Water characteristics
Limnogeology
Lake hydrology
Limnologic systems

Activities in each of the above fields are split into small units, research projects and subprojects.

WATER MOTION RESEARCH

The research encompasses the systematic studies of waves, tides, surges, seiches, currents, energy exchange at the air-water interface, interactions at the water-sediment interface, and flows in the Great Lakes and associated channels.

Following projects are active:

Lake currents
Harbor currents
Lake waves
Water level disturbances

Lake Currents

During the open water season of 1972 an extensive data collection took place in Lake Ontario as part of the International Field Year on the Great Lakes (IFYGL). Currents were traced by drogues placed at various depths and recorded by current meters suspended from buoys. Data reduction is underway and analysis will be started and continue through fiscal year 1973. No new field work is scheduled in the near future.

Harbor Currents

Systematic survey of currents in Oswego Harbor and in the surrounding area of Lake Ontario was accomplished during the past summer. In addition to tracing currents by drogues, extensive water sampling was performed. The aim is to establish pollution levels in a harbor and dispersal rates in a Lake as a function of current speed and water volume being transported. The data will be analyzed in fiscal year 1973.

Lake Waves

Five waverider buoys were operated in Lake Ontario during the past summer. One buoy was damaged and removed, and the other four provided outstanding wave record. A tower erected one mile from Oswego in Lake Ontario supported four staff and two pressure type wave sensors. Data were transmitted to shore and recorded on 7-channel tape. Early in summer the tower was hit by lightning and near the end of season damaged by storm. Wave record therefore is rather fragmentary. During 1973 six wave gages will be operated, two each in Lakes Superior, Michigan and Erie, and analysis of recorded waves in Lake Ontario completed.

Water Level Disturbances

Data from permanent and temporary water level gages around Lake Ontario will be reduced and stored for future analysis.

WATER CHARACTERISTICS RESEARCH

The research in this field involves collection, analysis, and interpretation of data pertaining or related to physical and chemical characteristics of the fresh water in the Great Lakes; definition of those water properties which may be utilized as indices of water characteristics and quality; development of systematic relationships of significant indices; and installation of permanent automatic monitor stations. Energy budgets and chemical budgets will be developed to establish dynamic relationships of the environment and to explain evaporation, lake currents, and other physical variables.

The research activity is split into three projects: lake water data; monitoring of water characteristics; and energy budget.

Lake Water Data

The physical, chemical, and biological properties of lake water are continuously changing due to such seasonal factors as heat input, lake stratification, ice cover, and many other factors. Wind-induced currents cause shifting of water masses and therefore change the character at a given location quite rapidly. For this reason the determination of lake water characteristics is a difficult task and requires repeated water sampling. A number of stations in a lake are selected and samples of water are taken six to eight times per open water season. A rather small vessel, *R/V Shenehon*, 65-feet long with 90-ton displacement is used for that purpose. The past summer, data collection in Lake Ontario was under IFYGL and NOAA ship *Researcher* was used. Next year *R/V Shenehon* will sample the southern part of Lake Michigan. Comprehensive data have been supplied to the Environmental Protection Agency (EPA), less extensive data to many other agencies.

Monitoring of Water Characteristics

Ten continuous automatic temperature recorders have been installed and in operation since 1965. This year the network was augmented by two permanent installations in the St. Lawrence River and eleven temporary gages in connection with Navigation Season Extension project. The temperature sensors are placed three meters below long-term mean water level. All stations will be operated through 1973. Data are available in table and punch card formats. Plans are made to establish a number of comprehensive monitor stations to record physical, chemical, and biological parameters. The hardware estimate approximates six million dollars and at present is unfunded.

Energy Budget

The natural and cultural factors causing variations in energy storage of the Lakes are being evaluated and energy budgets of individual Lakes as well as the total system will be established. Data for the project essentially come from the systematic sampling of the Lakes. In addition during the past summer data were collected on heat advection into and from Lake Ontario through Niagara and St. Lawrence Rivers. The report on Lake Ontario energy budget is scheduled for completion during fiscal year 1975.

LIMNOGEOLOGY RESEARCH

The research is designed to obtain knowledge on the sedimentology of the Great Lakes, lake bottom and shoreline characteristics including the effects on water quality, rates of littoral transport and shoreline changes, geologic history and the crustal movement in the Great Lakes region.

Three projects have been outlined as lake bottom characteristics, long-term shoreline changes, and coastal area sedimentation.

All projects are inactive at the present. Priority will be given to investigations of lake bottom characteristics with emphasis on the effects on water quality of various types of lake bottom at various water depths. Lake Erie is a prime example where lake bottom has very significant effect on water quality.

LAKE HYDROLOGY RESEARCH

The aims of lake hydrology research are to gather and analyze data on hydrologic factors affecting the Great Lakes such as inflow, outflow, precipitation, evaporation, ice cover, and snow accumulation. Purpose of the studies is to develop or improve methods to forecast water supply, lake levels, and the formation, extent, and breakup of ice cover.

Lake hydrology research has the largest number of projects due mostly to the great interest in lake ice for winter navigation: hydrologic data base, lake precipitation, lake evaporation, ice cover distribution, ice characteristics, and ice forecasting.

Hydrologic Data Base

This data base includes overlake precipitation, lake storage, evaporation, basin runoff, ice thickness, water temperature, and other not readily available data. The present activity is in the beginning-of-month water level data and basin runoff data. Data will be grouped by Lakes and published.

Lake Precipitation

A number of precipitation recorders were placed on small islands in the eastern end of Lake Ontario and on nearby shores. Similar network is being operated in Canada by the Canadian Department of the Environment. Fisher-Porter recording gages capable of seven months continuous operation are used. Analysis of data collected earlier on Lake Michigan is in progress and a report will be prepared in fiscal year 1974.

Lake Evaporation

Evaporation from a lake is determined by the water budget, mass transfer, and energy budget methods. Comparison of the results by these three methods gives assurance or raises questions for the quality of results. Lake Erie evaporation study is near completion and a report will be published in fiscal year 1974.

Ice Cover Distribution

Information is gathered on the aerial extent and structure of the Great Lakes ice cover by means of visual aerial charting and aerial photomapping. An aircraft for the visual charting is provided by Ninth Coast Guard District, Cleveland, Ohio. Photomapping is accomplished by U.S. Air Force. Flight schedules are coordinated with the Canadian Department of the Environment. In addition imagery is obtained in the wave spectra of visual (color), infrared, microwave and by side-looking radar. The ice charting was started in February

1963 and continued each winter since then. Data are published in annual ice reports. Findings of the systematic observations and graphical depiction of ice cover during mild, normal, and severe winters are presented in the *Great Lakes Ice Atlas*, second edition of which was published last year. Ice cover investigations will continue with emphasis on navigation lanes in support of Navigation Season Extension Program and on Lake Ontario as part of IFYGL program.

Ice Characteristics

Investigations are made of physical and chemical characteristics of the ice cover formed in the various climatic environments of the Great Lakes. The observations include ice thickness, crystal structure, ice floe shape and size, and characteristics of pressure features. Laboratory analysis includes crystallography, geochemistry and particulate matter. Program will continue. No reports are scheduled at the present.

Ice Forecasting

A definite need exists for forecasts of the formation, growth, movement, structural features, and break-up of the ice in the Great Lakes. Due to complexity and great variations of conditions in the Lakes Region, the forecasting procedures will be developed for smaller geographical locations and only for certain ice processes. Initially the procedures will be developed for forecasting the time of ice formation and ice break-up in the St. Lawrence River. This is a continuous project.

LIMNOLOGIC SYSTEM RESEARCH

The objectives of the limnologic systems studies are to develop process-response models to simulate the complex interrelationships that exist between the individual processes within the Great Lakes and their immediate environment. These models will provide the basis for optimum utilization of the water resources, stress and disaster predictions, and statistical analyses of random events.

At present two projects are outlined: limnology monographs and mathematical models.

Limnology Monographs

Work is underway to prepare a monograph on the Great Lakes limnology. It will include hydrological, physical, chemical, and biological processes of the Lakes. Periodical revisions will be issued as new knowledge becomes available.

Mathematical Models

Under this project a series of mathematical models of varying complexity will be developed depicting the relationships between various natural processes.

A hydrologic response model of the Great Lakes System has been developed and tested and hydraulic transient models have been developed and tested for the St. Clair and Detroit Rivers. A mass transport model is being considered for Lake Ontario to depict movements of water and suspended and dissolved materials.

RESEARCH PROGRAM PUBLICATIONS

Research programs of the Lake Survey Center are published annually and are available on request. The joint publication of U.S. and Canadian Research Directories and Project Forecasts will be resumed and such directory for 1973 will be published in March 1973. Researchers contributing to the directory will receive complimentary copies.

The Sea Grant Program in the Great Lakes Area

Leo S. Craig, Office of Sea Grant, National Oceanic and Atmospheric Administration, Department of Commerce

ABSTRACT

Sea Grant objectives, as stated in the 1966 Public Law which created it, relate specifically to marine education and training, applied research and predevelopment, and extension and advisory services. These objectives are being implemented by means of grant support on an individual project, coherent project, or institutional program basis. The Sea Grant Program has grown from its inception to the present (fiscal year '73) funding level of $21.2KK. Fifteen universities have attained Sea Grant institutional status, of which three (Michigan, SUNY/Cornell and Wisconsin) are in the Great Lakes area. Non-federal matching funds of approximately 40% of total augment the Sea Grant funding. Approximately 140 projects under various major categories are being pursued by these three institutions, most of which are particularly applicable to Great Lakes area problems. In addition, as a result of Grant activities in Lake Ontario connected with IFYGL, the University of Rochester has discovered very extensive sand deposits and the Cape Fear Technical Institute research vessel *Advance II* was made available to scientists for performing various studies and measurements there. It is anticipated that the Sea Grant Program will continue to grow in the Great Lakes area as well as elsewhere along the U.S. coasts, dependent of course on the availability of funding. Growth is expected to be most marked with regard to marine advisory services and research in support of coastal zone management.

* * *

The Sea Grant Program, created by the National Sea Grant College and Program Act of 1966, has three explicit objectives in the marine field:

1. Education: To accelerate the training and education of specialized manpower not being developed through existing programs.
2. Research: To initiate and support applied research and pre-development, particularly related to recovery and use of marine resources.
3. Advisory services: To disseminate knowledge and information about marine resource development to all interested and concerned sections of the nation through extension and advisory services.

These objectives are being implemented in accordance with principles of a long-range plan which provides grant support on (originally) three bases (now effectively four):

1. Individual projects: Awarded to an investigator for a single project.
2. Coherent projects: Awarded for multiple projects grouped around a common applied theme.
3. Institutional program: Of long-term duration covering the three objectives previously referred to.
4. Sea Grant college designation: Awarded as a result of an effective institutional program over a minimum period of three years.

Fifteen universities have attained Sea Grant institutional status, of which three (Michigan, SUNY/Cornell, and Wisconsin) are in the Great Lakes area. Of these fifteen, six (including Wisconsin) are now designated Sea Grant Colleges. It is anticipated that the remaining nine, as well as others to be added, will eventually attain this status.

Federal Funding of National Sea Grant Program

Fiscal year	68	69	70	71	72	73
Funding (X KK)	$ 5.0	$ 6.0	$ 9.0	$13.2	$17.7	$21.2*

*Appropriated, but may be partially withheld

Funding has increased yearly to the present level of $21.2KK. Non-federal matching funds of approximately 40% of total augment this funding.

The three Great Lakes institutions are presently engaged in approximately 140 individual projects under various categories. Most of these projects are particularly applicable to Great Lakes area problems.

FY-73 Sea Grant Program Funding: University of Michigan (12 Months effective 7-1-72)

Sea Grant funds	$ 949,400
Non-federal matching funds	$ 476,100
Total	$1,425,500
Approximate number of projects	30
Approximate percent of effort in Great Lakes area	Practically all

THRUSTS OF UNIVERSITY OF MICHIGAN SEA GRANT PROGRAM

1. Development of an ecosystem model of Lake Michigan
    a. Sufficient generality for use as a decision making tool to guide the regulation of industrial, community, and other activities around the Lake
    b. Program first focused on Grand Traverse Bay as an analogue model, and concentration is now on completion and exercise of pilot model
2. Projects on socio-economic, political, and technological implications of water quality decisions
3. Studies in coastal zone and shorelands management
4. Technology development
    a. Alternative methods of wastewater treatment

   b. New and improved equipment and techniques for the working diver
   c. Studies toward defining the environmental impacts of cooling towers
5. Education
6. Advisory services

Brief Description of the Programs

The major thrust of the program from its inception has been the development of an ecosystem model of Lake Michigan with sufficient generality that it could be exercised as a decision-making tool to guide the regulation of industrial, community, and other activities around the Lake. The program focused first on Grand Traverse Bay as an analogue model of Lake Michigan. Most of the effort to date, as it will for the following year, has concentrated on the completion and exercise of this pilot model, which should then be modified to simulate the larger Lake. A set of interrelated projects works toward collection of basic data for input to and checking of the model and to developing the model itself.

Another set of projects focuses on socio-economic, political, and technological implications of water quality decisions. They cover studies of required economics respecting water resources management and public policy and institutional interaction in the area. A gaming simulation is being developed that effectively teaches decision makers the complexity of interacting decisions and the impact with respect to water quality in the Lake areas critical to their activities. Studies are being carried on in the field of coastal zone and shorelands management covering the full range of technological and legislative interactions that must be considered in developing a national framework within which management of these resources can be carried out.

In the area of technology development, alternative methods of wastewater treatment applicable to specific coastal-zone problems are being developed. New and improved equipment and techniques for the working diver are being developed and, in cooperation with local electric power industries, a project will be started with the objective of defining the environmental impacts of cooling towers.

FY-73 Sea Grant Program Funding: State University of New York/Cornell (13 Months effective 10-1-72)

Sea Grant funds	$ 800,000
Non-federal matching funds	$ 627,000
Total	$1,427,000
Approximate number of projects	35
Approximate percent of effort in Great Lakes area	Over 50 percent

THRUSTS OF STATE UNIVERSITY OF NEW YORK/CORNELL SEA GRANT PROGRAM

Note: Includes four university centers of Albany, Binghamton, Buffalo, and Stony Brook. Five university college campuses at Fredonia, Cortland, Geneseo, Oswego and Buffalo, College of Environmental Science and Forestry at Syracuse, and participating colleges of Cornell University.

1. Power plant siting on Lake Ontario
2. Wetlands management
3. Socio-economic, organizational and legal factors in water resource management
4. Recreation
5. Coastal processes
6. Non-living resources
7. Fisheries management and development
8. Utilization of marine needs
9. Technology and engineering
10. Education
11. Advisory services

Brief Description of the Program

The program represents an unusually large integrated consortium of campuses. These will include the four university centers of Albany, Binghamton, Buffalo, and Stony Brook; five university college campuses at Fredonia, Geneseo, Cortland, Oswego, and Buffalo; the College of Environmental Science and Forestry at Syracuse; and the participating colleges of Cornell University. Program leadership rests with the New York Sea Grant Program Office of State University Central Administration in Albany. The problems of this state's coastline, bordering both the Great Lakes projects concerned with power plant siting on Lake Ontario; wetlands management; socio-economic, organizational, and legal factors in water resource management; recreation; coastal processes; non-living resources; fisheries management and development; utilization of marine weeds; aquaculture; and technology and engineering.

Under the education program scientific advisory internships for the New York State Assembly are proposed. The objective of this project is to provide graduate students who will serve as interns to the Office of the Scientific Advisor to the New York State Assembly under the direction of the scientific advisory staff and faculty advisors.

The Sea Grant advisory services are extension-program oriented. Emphasis will be on educational efforts in seven major subject areas: mariculture, commerical fisheries, power plant siting, wetlands, recreational industry, coastal management, and marine environmental education for minority use. While the advisory service activities draw heavily on the long experience of the Cornell cooperative extension capabilities, regional marine specialists will maintain field offices at key locations in the state.

FY-73 Sea Grant Program Funding: University of Wisconsin (12 Months effective 9-1-72)

Sea Grant funds	$1,100,000
Non-federal matching funds	$ 600,000
Total	$1,700,000
Approximate number of projects	80
Approximate percent of effort in Great Lakes area	Practically all

THRUSTS OF UNIVERSITY OF WISCONSIN SEA GRANT PROGRAM

Note: Includes six units of the university system–Green Bay, Madison, Milwaukee, Oshkosh, Superior and University Extension.

1. Biological resources and microcontaminants (toxic substance)
2. Water quality (development of criteria for establishing a monitoring program)
3. Green Bay research program (water quality)
4. Ports and commerce
5. Electric power
6. Policy studies (coastal zone)
7. Geo-environmental and mineral resources
8. New applications
9. Education
10. Advisory services

Brief Description of the Program

Six units of the University system will prosecute parts of the program (Green Bay, Madison, Milwaukee, Oshkosh, Superior and University Extension) involving some 100 faculty members, 85 graduate students and about 100 undergraduate students.

The program contains projects in education and advisory services and eight packages of related research efforts each with a strong element of interaction and coordination.

Biological Resources and Microcontaminants

This program is currently responding to a critical problem in the Great Lakes with investigations into the occurrence, fate and persistence of known toxic substances; their transport through the ecosystem; physiological effects of sublethal levels on aquatic organisms and subhuman animals; and the development of new food resources and processing methods.

Water Quality

This program looks to the development of criteria for establishing a water quality monitoring program including identification of available data and establishing their reliability and usefulness. The determination of the assimilative capacity of the Great Lakes and the impact of urban development on water quality is another objective for which studies centered on Milwaukee Harbor and vicinity are designed.

Green Bay Research Program

This program focuses on the wide spectrum of water quality problems in Green Bay, emphasizing the sources of the problems (physical, economic and political) and projecting appropriate schemes for improving the management of the system.

Ports and Commerce

The St. Lawrence Seaway and the Great Lakes ports face an era of rapid and radical change as a result of new developments in marine as well as land transportation. This program focuses on the attendant problems and has as its goal the rapid and smooth progress needed to enable the Seaway and the ports to reach their greatest potential.

Electric Power

The main problem addressed is the conflict between the growth of electric power production on the shores of the Lakes and the potential adverse environmental impact of this growth. The physical aspect of the thermal plumes in Lake Michigan and their influence upon the distribution and abundance of fishes is studied. The potential for turning thermal effluents into useful assets is also being investigated.

Policy Studies

Mainly aimed at coastal zone problems in the Great Lakes, this program will become directly involved with local governments, citizens groups, and industrial organizations while studying the consequences of past and present actions and developing effective ways to explore future options open to them.

Geo-Environmental and Mineral Resources

In this program a team that has gained the reputation of being in the forefront of University expertise in marine mining will work in close collaboration with major industries and the federal agencies on surveys of mineable offshore resources in the Great Lakes, Alaskan waters and elsewhere. They will study the environmental, political and legal problems of ocean mining and work to develop methods of mineral recovery that minimize environmental damage.

New Applications

New applications include two small efforts, one looking at corrosion of different types of steels in the peculiar environments of Great Lakes waters and surficial sediments, and one investigating the design of simple devices to assist scuba divers.

Within several of the research programs there are activities coupling the researchers directly to user groups. There is also an organized advisory services program that covers a full range of activities including conferences, publications for public use, television spots and the interaction with the public through extension agents.

INDIVIDUAL SEA GRANT PROJECTS IN GREAT LAKES AREA

1. University of Rochester has reported locating economically significant sand beds in Lake Ontario, near Rochester. Estimated value $90 KK to $150 KK.
2. Cape Fear Technical Institute research vessel *Advance II* operating in Lake Ontario since late spring in support of IFYGL.

Despite recent indications of stringent curtailment of federal expenditures, we of Sea Grant are hopeful that the funding and program will continue to grow in the Great Lakes area, as well as throughout the country. Growth is expected to be most marked with regard to marine advisory services and research in support of coastal zone management.

THE CHARTING PROGRAM ON THE GREAT LAKES

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ABSTRACT

A program of nautical charting of the Great Lakes conducted by the Lake Survey Center, National Ocean Survey (NOS), National Oceanic and Atmospheric Administration (NOAA), Department of Commerce (DOC), serves the needs of many users of Great Lakes waters and others, including the general public, all levels of government, and commercial enterprises. While the production of navigation charts for all classes of vessels is the primary purpose of the program, important aspects of the program also involve measurements of lake levels, vertical and horizontal control surveys, special map compilation and printing services, consultation, and other support services to various governmental boards and committees. Throughout the program a very significant degree of coordination with Canadian agencies is maintained.

* * *

The Great Lakes and connecting channels comprise a waterway system which has long been recognized as one of the busiest in the world. For example, Great Lakes shipping now totals over 200 million tons a year, while the eight states bordering on the Great Lakes had a combined boat registration in 1970 of 2,080,581, 40.6% of the total registered boats in the nation. Because of the extensive use of this waterways system by both commercial and recreational boating, a complete and reliable charting program is essential to assure safe navigation through the use of accurate, easy to handle, nautical charts containing the latest navigation information possible.

The nautical charting service of the Lake Survey Center in support of the mission of the Department of Commerce produces direct benefits to industry and commerce of the United States in the guidance of marine traffic along the Great Lakes and connecting waterways. This mission is an important component of the nautical charting program of the Nautical Ocean Survey and complements the efforts of the Office of Marine Surveys and Maps. Nautical charts provided include coverage of (a) the Great Lakes, (b) Lake St. Clair, (c) the St. Marys, St. Clair, Detroit, and Niagara Rivers, (d) the St. Lawrence River between Lake Ontario and St. Regis, New York, (e) the New York State Barge Canal System between Lyons and Troy, New York, including Cayuga, Seneca, and Oneida Lakes and the Oswego Canal, (f) Lake Champlain, (g) the Hudson River between Troy and Whitehall, New York, (h) Lake of the Woods, (i) the Minnesota-Ontario border lakes between International Falls and North Lake, Minnesota.

The program objectives are to complete and maintain on an up-to-date basis the 144 charts of these waters for the safe and efficient navigation of commercial, fishing, and recreational craft and other marine traffic and to carry out corollary activities concerning horizontal control, vertical control, and water levels measurements and analysis. In addition, special support is provided to a number of national and international boards and commissions, especially groups serving the International Joint Commission. In carrying out these objectives, a systematic effort is maintained to obtain current charting information on this developing area and to use these data in a continuous process of updating the charts. Specifics of present chart coverage, especially scales and areas of individual charts, are the result of an evolutionary process of adapting the charting program to the needs of the product users since the publication of the first Lake Survey chart in 1853. However, to meet more adequately the navigational needs of the expanding fleet of commercial and pleasure craft, modifications of the format and coverage of many of the charts must be considered.

Although the charting program was established for the benefit of commercial vessels and still is principally so intended, rapidly increasing operation of recreational boats has required recognition of recreational charting needs. It is now expected that the charting requirements for recreation will rival the requirements for commerce, although divergent in format.

Establishment of charting requirements and justification of the compilation and printing of charts to meet the requirements can be difficult problems. The latter problem especially can be difficult since not every requirement justifies the production of a new chart or revision of an existing chart. Although ultimately the chart users establish requirements and justifications, this information is not normally available prior to production of a given chart and the subsequent user responses. The problems are eased considerably in the case of the commercial navigation charts by the continuing liaison that is maintained with the Lakes Carriers' Association of Cleveland, Ohio, which represents owners of a large part of the United States Great Lakes domestic commercial fleet. In the case of recreational charts, despite numerous contacts with individual chart buyers, chart sales agents, U.S. Power Squadrons, and Coast Guard Auxiliaries, the needed information cannot be quickly acquired because the users are often unable to define their requirements.

The specific activities of the Lake Survey Center included with the NOAA Great Lakes nautical charting program are described in the following paragraphs.

Chart Compilation

The Lake Survey compiles 144 numbered charts. Of these, seven are chart books containing from 12 to 61 charts each. The chart books, two specially formatted and folded charts of the St. Clair and Detroit Rivers, and 14 of the 18 Minnesota-Ontario border lakes charts are intended principally for the use of recreational craft operators. The remaining charts are intended for the use of commercial operators. Scales of the charts vary from 1:5,000 in the chart books to 1:1,500,000 for a general chart of the Great Lakes. Numerous large scale harbor insets are shown on smaller scale charts. Except for the international waters of the connecting rivers, which are charted in detail, Canadian areas are charted only on a few small scale charts.

Most Lake Survey charts are revised at intervals of three years. New editions are printed and unsold copies of the prior editions are cancelled. This policy was begun over 30 years ago. It was keyed to the concurrent policy of hand correcting aids-to-navigation on charts in stock to the date of sale, on the basis that the cost of hand correcting an average chart became equal to the cost of printing a new edition after three years. Hand correction of charts to date of sale was abandoned in 1969 because of difficulty in maintaining a staff for this work. The three-year new edition policy remains a sound one for many charts, however, because in three years enough changes occur to warrant a new edition for the protection and convenience of the users. Present general policy is to consider each chart on an ad hoc basis; some are therefore revised at one-year intervals while others are revised only after six years or more. An increasing volume of chart changes is causing an increasing need for producing new editions at one or one-and-a-half year intervals. As a substitute for hand corrections, changes in aids-to-navigation are overprinted on charts in stock yearly during the winter season when ship transits are at a minimum.

In the compilation process, the survey data acquired in field operations and supplementary data, obtained from numerous federal, state and municipal agencies and private organizations, are analyzed and, as appropriate, necessary revisions based on these data are applied to special plastic copies of the charts. These revised copies are utilized in the preparation of lithographic plates for chart reproduction. The supplementary data may consist of notices to mariners concerning changes in one or more of the thousands of United States and Canadian aids-to-navigation shown on the charts or reports of changes in channels or structures maintained by the Corps of Engineers and of the completion of pipelines, cables, and other construction authorized by permits issued by that agency.

A relatively new source of supplementary data are reports received from individual boaters through the cooperative Charting Program with the U.S. Power Squadrons and the Chart Verification Program with the U.S. Coast Guard Auxiliary Flotillas in the Ninth Coast Guard District. An increasing number of such reports are received each year. The total in 1971 was almost 800.

A continuing effort has been made (and even more effort is needed) to design and publish nautical charts suited to the changing requirements of commercial navigation and the rapidly expanding recreational craft fleet. Studies have been made and user surveys undertaken to determine trends in the development of the Great Lakes area, to obtain data on charting requirements and to foresee the areas where new surveys and chart coverage will be required. While many modifications in chart format and coverage have been accomplished, an increased production rate on new chart design and construction must be maintained to adequately fill the needs of a growing economy.

Reproduction and Dissemination

After the new chart has been compiled, new color separation negatives are prepared and engraved and lithographic plates are processed. For new editions of charts, the compiled revisions are engraved on the negatives of the previous edition and new lithographic plates are processed. The supply of charts is required to last until the next edition is printed.

Of the 144 charts published by the Lake Survey, 11 charts are updated at six to ten year intervals, 117 are printed triennially, 10 are printed at one and one-half year intervals and six are printed annually. This schedule is based on the history of changes in the charted areas. Charts of areas with more numerous and frequent changes are printed at shorter intervals.

Changes of major significance occurring between scheduled printings are corrected by surprinting. However, in general, corrections to the chart between prints must be made by the user from information distributed in notices to mariners and supplements to the *Great Lakes Pilot*. There is a serious deficiency in the dissemination of information on changes since most users do not secure these publications, and the description of many changes cannot readily be included in the publications.

About one-half of the printing resource available is employed in production of the Lake Survey charts; the remainder is used for reimbursable work such as production of project maps for the Corps of Engineers and compilation of special maps for various agencies. Recently, for example, a significant amount of engraving and printing support is being furnished to the Great Lakes Basin Commission and International Great Lakes Levels Board. Printing support is also being furnished to the Reproduction Division, National Ocean Survey, and to the National Weather Service.

Charts and related publications may be purchased from 215 authorized sales agents in the United States and Canada and from the Lake Survey Center, NOS, Detroit, Michigan. Mail orders are filled by the Lake Survey Center.

Hydrographic and Topographic Surveys

Shortly after World War II, it had been concluded that a comprehensive resurvey of depths of the Great Lakes was warranted, particularly in areas where the most recent surveys were 50 or more years old. The work involved fell into two categories based on the concept (which is substantially valid today) that any obstruction or shoal more than 36-feet below the surface is not a hazard to navigation. These categories became known as inshore surveys, covering waters from the shore to 36 feet depth, and offshore surveys, covering waters deeper than 36 feet. Although the former is by definition more critical, the latter was given priority because the survey vessel position in almost all of the previous offshore surveys was obtained by dead reckoning, a method which could lead to errors of several miles in running cross-lake sounding lines, and very accurate electronic positioning methods had become available. The offshore survey program was started in the early 1950s and completed in about 10 years. Electronic positioning devices used, in chronological order, were Raydist, EPI and Shoran. All Lakes were covered at a line spacing of three miles except Lake Huron, including many areas within Canada.

While the offshore program was on-going some inshore surveys were made. When the offshore program was completed the inshore program could not be given the desired impetus because of shortages of money and personnel and because topographic surveys and control surveys were (and still are) of higher priority than inshore surveys. The shortages continued to worsen and the yearly amount of inshore surveying steadily diminished. In the field season of 1969 no inshore surveys were made, in the field season of 1970 only limited, special purpose surveys were made, and in the field season of 1971 only a single, brief special purpose survey was made.

Over 2,000 miles of inshore areas of the Great Lakes plus Lake of the Woods, Oneida Lake, Cayuga Lake, Seneca Lake, and Lake Champlain have not been surveyed since before 1940, and the surveys of a large percentage of these areas were made before 1875. With a single survey vessel and an average field season of five months per year this work would require an estimated 8-10 years to complete. However, requirements for sweep surveys (see below) and special surveys for other agencies could be expected to extend the period to 10 to 12 years. With one survey vessel and two small boats sounding simultaneously (a system that has been used successfully), the program can probably be completed in 6-8 years (with allowances for special work).

The Lake Survey has used electronic positioning systems for sounding surveys for many years. For the past two years, investigations have been underway of the automation of sounding surveys, i.e., the digitization and automatic plotting of depth and position data. These investigations have led to identification of suitable hardware, procurement of which is being planned in coordination with other units of the National Ocean Survey to insure compatibility.

Wire sweeping consists of pulling a wire up to 2,400 feet in length through the water horizontally suspended at a fixed depth. It is used to determine the unobstructed depth (up to 36 feet) in a given area with greater confidence than can be obtained with ordinary sounding lines. Principal need for sweeping is in approaches to harbors. Occasionally a wreck or other obstruction will create a need for sweeping. There are at present a number of harbors where sweeping should be undertaken. This work is usually carried out in combination with inshore surveys. Side-looking sonar to be used in place of the wire sweep has been investigated but thus far found to be inadequate.

In order to provide information for new editions of charts, periodic hydrographic and topographic surveys, known as revisory surveys, of all United States harbors on the Great Lakes are made. Shoreline areas between harbors are not surveyed on a short term periodic basis, changes in these areas being found during the course of inshore surveys or from special sources. This work is scheduled so that a field survey of each United States harbor on the Lakes and connecting rivers can be made once every three years.

Specific hydrographic and topographic work performed in the course of revisory surveys is as follows:

A. Comparing waterfront topography with that shown on the chart and making necessary surveys for correcting the chart where changes are detected. Wherever possible, recent aerial photos or surveys of other organizations are procured, field checked and used in place of making an instrumental survey. As required, control surveys are made to locate photo control points.

B. Verifying or reviewing all names shown on the chart and obtaining additional pertinent names.

C. Verifying or revising statements in the *Great Lakes Pilot*. All statements contained therein that are not the direct responsibility of other organizations are field checked.

D. Sounding approaches to harbors, as described in the following paragraph.

E. Checking charted depths in areas outside of federal navigation projects, such as along dock faces and in slips.

Federal navigation projects, which provide given minimum depths, exist in many harbors, the required dredging being conducted under the supervision of the Corps of Engineers. These projects generally do not extend very far lakeward of the harbor entrances, and the danger exists that shoaling of the Lake approaches to the harbors will produce depths less than the project depths. Examination soundings are therefore obtained in and around entrances to harbors and channels. Where the examination soundings indicate a need for more detailed coverage this work is performed at once.

Horizontal Control Surveys

A necessary concomitant of hydrographic surveys are horizontal control surveys. The initial effort of establishing a network of well-monumented triangulation stations around the shores of the Great Lakes began in the late 1850s. Requiring many years to complete, this work continued until near the end of the nineteenth century with the most active period being 1867-1879. In 1902, all parts of the Lake Survey network were incorporated into, and adjusted with the national network established by the U.S. Coast and Geodetic Survey. A further adjustment of Lake Survey triangulation was made to achieve conformity with the U.S. Coast and Geodetic Survey's "North American Datum Adjustment of 1927." After 1900 the Lake Survey undertook only very limited first order horizontal control work. Most recently, certain first order control was established and recovered along the St. Lawrence River in the mid-1950s in support of the Seaway Project. Since that time, no extension of the first order net or re-establishment of stations has been accomplished. Second and third order stations were established only as required for hydrographic surveys and for special purposes of other offices of the Corps of Engineers.

It is estimated that of the first order stations originally established in the Lake Survey network, approximately one-third have been destroyed, and of the second and third order stations, about one-half have been destroyed. Some recovery work has been carried out as needed for current surveys; however, a substantial program of triangulation recovery is needed to determine the extent of new work required. To conform to the guidelines set forth in BOB Circular A-16, dated May 6, 1967, to be compatible with the national network, and to meet the specific needs of the Lake Survey and other agencies, first order stations should be available in major harbors and at an average spacing of 10 to 15 miles along the shore line and second order stations should be available at most other harbors and at an average spacing of 5 to 10 miles along the shore line.

The Lake Survey Center does not have the capability to establish first order horizontal control stations, consequently, this work would be more efficiently accomplished by the National Geodetic Survey. However, second order horizontal control can be established and maintained by the Lake Survey.

Latest available descriptions and positions on North American Datum of 1927 for all stations are filed in a one degree of latitude and longitude quadrangle system which covers the entire Great Lakes working area of the Lake Survey Center and contains stations of the Lake Survey and National Geodetic Survey. Lake Survey data is updated whenever information is received on stations from field parties or other sources. National Geodetic Survey data is added to the files as information is received from their automatic mailing list. An alphabetical card index by station name is maintained for all stations, giving the one degree quadrangle within which each station is located and the location in the archives of field notes for each station. These data are used to answer frequent requests from the general public as well as to support programs of the Lake Survey Center, Corps of Engineers and other federal agencies.

To supplement revisory surveys in obtaining topographical detail and horizontal control surveys in establishing second and lower order control points, a photogrammetry facility is maintained. This facility has the capability of stereocompilation and analytic aerotriangulation and has a library of aerial photos of the Great Lakes.

Vertical Control Surveys

The water levels of the Great Lakes and their outflow rivers are continually changing in both a cyclic and a random manner. Interpretation of charted depths at a given time therefore requires a vertical reference system, i.e., vertical control. However, requirements of vertical control on the Great Lakes for construction projects are also of great importance.

Although reference planes for lake levels and depths had been established by the Lake Survey on each of the Lakes prior to 1875, no program of connecting benchmarks throughout the region by level lines was undertaken until that year. In the period 1875-1877, the Lake Survey determined sea level elevations over the entire Great Lakes region, the starting point being Rensselaer, New York where the U.S. Coast and Geodetic Survey had provided a level connection to the tide gage at New York City in 1875. Two leveling procedures were used. Along the connecting rivers, instrumental level lines were run. On each Lake, elevation was transferred from the terminus of the instrumental level line to other points by water levels. The procedure of water level transfer of elevation involves obtaining concurrent water levels at the starting point and the new point over a period of several months, and is based on the assumption that averaged over the period of observation the water levels at the two points will be equal. (These two procedures, with improvements in technique, are in use today.)

About the beginning of the present century, the Lake Survey and the Coast Survey made a redetermination of sea level elevations in the Great Lakes area. Collectively these redeterminations became known as 1903 Datum and were the substantive basis of the Lake Survey's vertical control until the establishment of International Great Lakes Datum (1955).

Also about the beginning of the present century it became known, by means of water level transfers, that benchmarks at different locations on the same Lake were undergoing slow, progressive changes in elevation with respect to each other. The phenomenon has been generally called "crustal movement" based on the theory that it results from differential tilting of the earth's crust. There remains, however, some doubt as to the cause. The magnitude of the effect may be as large as one foot per 100 years and generally is a few tenths of a foot per hundred years.

By 1935, crustal movement had caused relative elevations of many benchmarks to depart from their nominal 1903 datum difference by unacceptable amounts. On each Lake except Lake Superior the nominal 1903 Datum elevation above sea level of a single master benchmark was retained, and the then existing elevation differences between the master benchmark and other benchmarks on the same Lake were determined by water level transfers. The differences so determined were used to revise the nominal elevations above sea level of the benchmarks other than the master benchmarks. This adjustment of elevations is identified as 1935 Datum. A similar procedure was followed for Lake Superior except that the elevation of the master benchmark at Point Iroquois was determined by a 1934 instrumental level line from DeTour on Lake Huron.

The Corps of Engineers, as the agency then responsible for the federal programs of charting and navigation improvements on the Great Lakes, established reference, or datum, planes (a plane in this sense being a gravitationally level surface) early in the history of these programs. Initially, different planes were used on the same Lake for charting and for navigation improvements with different planes sometimes being used for navigation improvements in different harbors on the same Lake.

In 1933, the Chief of Engineers established a single plane on each Lake, known as Low Water Datum (LWD), to be used both for charting and improvement work. Since charting the Lakes is now a function of NOAA while the Corps retains the construction function, any changes of the Low Water Datum, which could become desirable for various reasons, would have to be coordinated between the two agencies. Certain Canadian agencies would be involved as well. Such coordination could most appropriately and effectively be accomplished by the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data (described below).

In the early 1950s, very high levels of the Lakes and the imminent implementation of the St. Lawrence River seaway and power projects created an immediate need for international coordination of basic data, especially lake levels and outflows. To meet this need, the Corps of Engineers and three Canadian federal departments formed in 1953 the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data.

Among the problems to which the Coordinating Committee addressed itself was the establishment of an international vertical datum to replace the several datums then in use including the Lake Survey's 1935 Datum. A coordinated program of water level observations and instrumental leveling was undertaken. This resulted in the establishment of a new datum, which was adopted for general use in 1960, and called the International Great Lakes Datum (1955). The new datum differs from the 1903 and 1935 datums in that the basic reference point is mean water level at Pointe-au-Pere, Quebec, on the Gulf of St. Lawrence instead of mean level at New York City, and in that elevation differences referring to the new datum have dynamic values instead of instrumental values. Crustal movement effects were eliminated as of the year 1955, i.e., the revised benchmark elevations show the elevation differences existing in 1955. Adoption of the new datum changed the position of Low Water Datum of each Lake with respect to the master benchmark of that Lake by only an insignificant amount.

The overall vertical control program of the Lake Survey consists of maintenance of a file of descriptions and elevations of about 2,250 benchmarks and periodic instrumental and water transfer leveling to these marks. About 1,450 of the benchmarks are found in small groups at over 200 separate sites which are harbors and/or water level gaging sites. The remainder are relatively widely spaced along the precise level lines between these sites. Within the overall program, specific present programs include maintenance of vertical control at harbors where there are United States federal navigation improvement projects, and the updating of International Great Lakes Datum (1955). These specific programs are described in the paragraphs following.

Common levels are run at least once yearly at each gage site to check stability. Part of this work is accomplished in the course of triennial revisory surveys of United States harbors for the purpose of chart revision. The remainder is accomplished as part of a regular program of water level gage maintenance. Also in the course of the revisory surveys, common levels are run and, as necessary, temporary water level gages are installed at all locations of United States federal navigation improvement projects on the Great Lakes and connecting rivers. The data therefrom are used by the Lake Survey to maintain the vertical control and to determine the amount of crustal movement with respect to LWD occurring since 1955. Elevations referred to LWD are needed by the Corps of Engineers to insure compatibility of navigation improvement projects on each Lake.

Several years ago the Coordinating Committee recommended to appropriate United States and Canadian agencies, including the Lake Survey, that a data collection program similar to that on which the establishment of International Great Lakes Datum (1955) was based be again undertaken for the purpose of possible updating of the 1955 Datum. This program was begun in 1967 and will be completed in 1973. Whether or not a new datum will be established will not be determined until data collection and analysis are completed. Since 1967 most of the vertical control survey effort of the Lake Survey Center has been expended on the precise leveling programs required for the new datum determinations.

Water Level Gaging

The Lake Survey began a continuing determination of levels of the Great Lakes with the installation of a few water level gaging stations in 1859. Prior to this time some records of lake levels, both continuing and sporadic, had been collected by other agencies and individuals. The Lake Survey's 1859 water level gages and the earlier gages as well consisted merely of benchmarks from which periodic manual measurements of the vertical distance to the water surface were made. Principal purposes of the 1859 gages were to define the general character of lake level variations and to relate lake levels to hydrographic surveys.

After 1859 there occurred an increasing recognition of the need for lake level data for a multitude of purposes including, for example, determination of the flow of water from one Lake to another and the determination of the effects of artificial changes in the hydraulic system of the Great Lakes. The Sundry Civil Act of 4 June 1897 provided for lake level observations and investigations made necessary by the improvement of channels of the Great Lakes between Chicago, Duluth and Buffalo. This led to the formalization of a lake level project for the Lake Survey as described in the Annual Report of the Chief of Engineers for 1898, pages 3774-3775. The lake levels project described therein has been continued to the present and expanded as the need became apparent. In 1898 the Lake Survey operated 12 water level gaging stations. In 1972, 51 continuing stations are being operated and 60-80 temporary gages are operated each year for various special purposes.

Most requirements for water level data are of continuing nature, i.e., termination or interruption of the requirement is not foreseeable. Some requirements are of non-continuing or temporary nature, such as data that are needed for a foreseeably terminating, although occasionally recurring, purpose or period. Requirements are far reaching. Almost all use and development of the water resources of the Great Lakes involve these data to an essential degree. Users include many thousands of private boat and real estate owners, shipping companies, power companies, many other businesses, and public agencies. While some water level data are being collected privately and by public agencies other than the Lake Survey Center, the large portion of the water level gaging network of the Great Lakes had been and is being undertaken as a federal responsibility with the Lake Survey as the responsible agency. In discharging this responsibility, the Lake Survey must not only provide for current data requirements but also provide for anticipated future requirements. Specific uses of water level data include the following principal uses:

A. for navigation and piloting of commercial vessels
B. for navigation or recreational boats
C. for maintenance of vertical control
D. for operation of the Lake Superior and Lake Ontario regulation plans
E. for studies of the regulation of the Great Lakes
F. for hydraulic and hydrologic engineering studies, including the determination of flows of the outflow rivers and beach erosion studies
G. for water resource development research

H. for environmental impact review
I. for coastal zone management studies and shoreline construction projects
J. for routine periodic publication
K. for answering individual requests for information

Records from Lake Survey water level gages, some of which are digital records and others analog, are removed from the gage instruments once or twice each month by contract gage observers and forwarded to the Lake Survey office in Detroit. There the records are processed and published in various formats. Most significant of the publications is the *Monthly Bulletin of Lake Levels*, which is sent without charge to over 6,000 recipients.

As an adjunct to the water level gaging program, and often to support international groups, technical studies are carried out on such subjects as gaging techniques, gaging patterns, lake level forecasting, effects of storms, and gravity anomalies. For example, a study was made recently for the International Niagara Board of Control on the optimum location of the gage in the American Falls Channel at Niagara Falls.

Products and Services

In addition to a planning chart covering the entire area charted by the Lake Survey center on a sheet 30 inches by 42 inches at a scale of 1:1,500,000, the major chart coverage is on sheets ranging in size from 26 inches by 30 inches to 36 inches by 48 inches and in scale from 1:5,000 to 1:600,000. These charts which serve maritime interests for the safe navigation of vessels, large and small, are most conveniently used on the plotting tables of larger boats. The depiction of hydrography and topography and other symbolized data on the charts is used also by commerce, industry, science and government in many other ways. The charts may be classified as follows:

A. General charts: These are nautical charts of each of the Great Lakes at scales from 1:400,000 to 1:600,000. They are designed for navigation along and across the Lakes when a vessel is well offshore.

B. Coast charts: These are nautical charts at scales from 1:40,000 to 1:120,000. They are intended for close coastal navigation and for approaching and departing harbors.

C. River charts: These are nautical charts at scales from 1:30,000 to 1:60,000 and are designed for use in navigating the major rivers between the lakes.

D. Harbor charts: These are nautical charts at scales larger than 1:40,000. The scale depends on the size, importance and character of the harbor. Harbor charts are intended for navigating into, out of, and in the harbors and tributary rivers. For convenience, many harbors are charted as insets on the Coast Charts instead of on individual charts.

E. Small-craft charts: These are nautical charts arranged in book form with 11-inch by 17-1/2 inch sheets, a size and design suited to easy reference and plotting in the limited space aboard small craft. The basic chart coverage in these books is at a scale of 1:15,000 with harbor plans at larger scales and plotting and planning sheets at smaller scales. The books also contain information on "Rules of the Road," on lights required on boats, on chart symbols and usage, and on "MAFOR" and other weather forecasts.

Complementing the navigational information shown on the charts is the *Great Lakes Pilot*, an approximately 600-page descriptive publication. It provides the mariner with full descriptions of physical conditions of the water charted and information not adapted to adequate or prompt representation on the charts, such as United States laws and local ordinances governing navigation, tables of distances between points on the Great Lakes System, bridge clearances, signals for locks and bridges, dimensions and capacities of dry docks and marine railways, and hydraulic and climatological data.

New editions of the Pilot are published annually at the start of navigation on the Great Lakes, and supplements to the current edition are published monthly during the navigation season, May through October, and sent to those who have obtained the current edition. The supplements contain information on current lake levels and provide additions and corrections to the Pilot text occasioned by constantly changing conditions in the navigational areas.

Other products and services include the following:

A. *Monthly Bulletin of Lake Levels*, showing current levels of the Great Lakes and Lake St. Clair, levels of the prior 12 or 13 months, and probable levels of the next 6 months, is published for the benefit of mariners. During the period April to December, these bulletins are published semimonthly and, in addition to the data shown on the Monthly Bulletin, show the existing or expected levels of the Great Lakes connecting channels with reference to chart datum and the maintained depths referred to chart datum along the connecting channels. The probable levels and connecting channels reports are furnished by the Corps of Engineers.

B. A hydrograph of lake levels showing monthly mean levels of the Great Lakes from 1860 to date and of Lake St. Clair from 1898 to date is updated and printed semi-annually.

C. Tabulations of water levels data in various formats are compiled and published.

D. Tabulations of precipitation over the Great Lakes Basin, diversions of water into and out of the Great Lakes Basin, and flows of the outflow rivers of the Great Lakes are compiled from data furnished by the National Weather Service and Corps of Engineers and published.

E. Data generated by all of the surveying programs are furnished to requestors.

F. Consulting services are furnished to a number of international boards and committees in the fields of map production, lake regulation, hydraulics of the outflow river, general hydrology, water level measurement, and others.

G. Many other products and services are furnished as described above in relation to the several specific activities included in the nautical charting program.

Coordination with Canada

To conclude this description of the Great Lakes charting program, it is appropriate to describe how the program relates to similar efforts of Canada since the Great Lakes, except Lake Michigan, are owned by both countries. The Lake Survey Center maintains close liaison with their Canadian counterpart, the Canadian Hydrographic Service (CHS). This liaison involves the discussion of charting matters of common interest to both agencies and making suggestions on improving the chart product of both countries. To assist the liaison, CHS and the Lake Survey Center established an ad-hoc coordinating group called the Charting Advisors in 1963. The Charting Advisors conduct a program of international participation through which plans, ideas, and suggestions of mutual concern for improving existing or developing future charts are exchanged. Principal items considered by the Charting Advisors are:

A. Nautical chart categories, coverage, layout, scales, and projections
B. Chart symbols
C. Chart maintenance and notices to mariners
D. Notational standards including credit lines and datum notes on charts
E. Charting and standard procedures for surveys and compilation methods
F. Chart production cycles; new edictions, corrected reprints
G. Exchange of navigational data
H. Catalogues; frequency of publications, coverage and use of information bulletins
I. Chart distribution and pricing policies
J. Gratuitous issue policy for international distribution of charts and publications
K. Pilots; contents, format, organization, coverage, and method of updating
L. Revisory surveys--techniques and frequency
M. Chart reference planes (low water datum)

Continuation of the efforts of the Charting Advisors is essential to the future coordination of the charting program of the two countries.

The foregoing fields of United States–Canadian coordination concern mainly the production of navigation charts. Equally important is the coordination being conducted in the fields of control (vertical, as described above in relation to the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, and horizontal), water level measurements, and hydraulics and hydrology. In these fields as well, close liaison is maintained with counterpart Canadian agencies and data and results are regularly exchanged. One of the most interesting and significant coordinating efforts now underway is that aimed at publication of internationally coordinated long range lake level forecasts. Much of the required coordination in all fields is effected by memberships of charting personnel on international boards and committees and/or their participation in the activities of such groups.

International Field Year for the Great Lakes

Eugene J. Aubert, IFYGL Project Office,
National Oceanic and Atmospheric Administration,
Department of Commerce

ABSTRACT

The International Field Year for the Great Lakes (IFYGL) is an experimental field program designed to improve knowledge of the limnology, hydrology, and meteorology of Lake Ontario and the Ontario basin. Through this improved knowledge the program will provide a scientific basis for better Great Lakes management in terms of water quality and quantity as well as environmentally sensitive operations. Approximately 1,000 United States and Canadian participants from federal, state, and provincial agencies, and universities and private institutions are involved in IFYGL.

Observations are being made to describe such large-scale natural processes as terrestrial water balance, atmospheric water balance, lake heat balance, and materials balance of selected chemicals. From these projects and boundary layer observations a synthesis of lake evaporation estimates will be made by both direct and indirect methods. Distributions and variability of physical, chemical, and biological parameters are also being observed, and modeling and simulation approaches are being used to develop tools for water resource management. The one-year data collection phase is underway and will continue into the spring of 1973.

Systems used for intensive monitoring of Lake Ontario and its basin include ships, buoys, towers, radar, aircraft, balloons, and satellites. Water chemical and biological analyses are being performed aboard ship as well as in government and private laboratories. The analysis phase of IFYGL is expected to continue until 1976. Major scientific and technical findings should begin to become available in 1974.

* * *

INTRODUCTION

Conceived as a part of the International Hydrologic Decade (1965-1974), the International Field Year for the Great Lakes (IFYGL) is a joint United States-Canadian program of environmental and water resources research focusing on Lake Ontario and the Ontario basin. The field data collection is underway and will continue until the spring of 1973. Some data acquisition systems have been in continuous operation since the Field Year began in April 1972, some have operated continuously for shorter periods, and others have operated intermittently. Approximately 1,000 individuals from the United States and Canada are participating in IFYGL, some of the U.S. participants representing seven U.S. federal departments and independent agencies. An overview of the experimental program from the vantage point of the U.S. IFYGL Project Office in the National Oceanic and Atmospheric Administration (NOAA) is given in the sections that follow, which describe IFYGL planning, objectives, management, scientific research areas, and supporting activities.

IFYGL OBJECTIVE AND SCOPE

The central objective of IFYGL is to strengthen knowledge of Lake Ontario and the Ontario basin in order to provide a scientific basis for improved Great Lakes management activities related to water quality and quantity and environmentally sensitive operations. Examples of such activities are the provision of municipal, industrial, and rural water supply; protection of water quality; fish resource management; optimization of commercial and recreational navigation; control of water levels and flows; provision of hydropower; shore use and erosion control; and warnings of hazardous and destructive conditions.

COORDINATION AND MANAGEMENT

As IFYGL is part of the International Hydrological Decade (IHD), the National Committees of the IHD in the United States and Canada established an International Steering Committee for IFYGL (Figure 1). The International Steering Committee undertook broad planning and established policy. Policy implementation and continued coordination is the responsibility of the Joint Management Team, which is made up of the Canadian Management Team and the U.S. IFYGL Project Office. Coordination efforts are supported by six scientific panels concerned with the terrestrial water balance, energy budget, lake meteorology and evaporation, boundary layer, water movement, and biology and chemistry. Coordination of the actual field operations and of data management takes place between individuals in the United States and Canada identified by the Joint Management Team.

Seven major U.S. government departments and independent agencies, and the New York Department of Environmental Conservation, are participating in IFYGL (Table 1). In addition, private institutions are involved in the international field experiment (Table 2).

National Oceanic and Atmospheric Administration, the U.S. lead agency for IFYGL, has established a U.S. IFYGL Project Office, which carries responsibility for the U.S. field operations, data acquisition system engineering and testing, data management, and scientific studies. Six major components within NOAA support the Project Office activities.

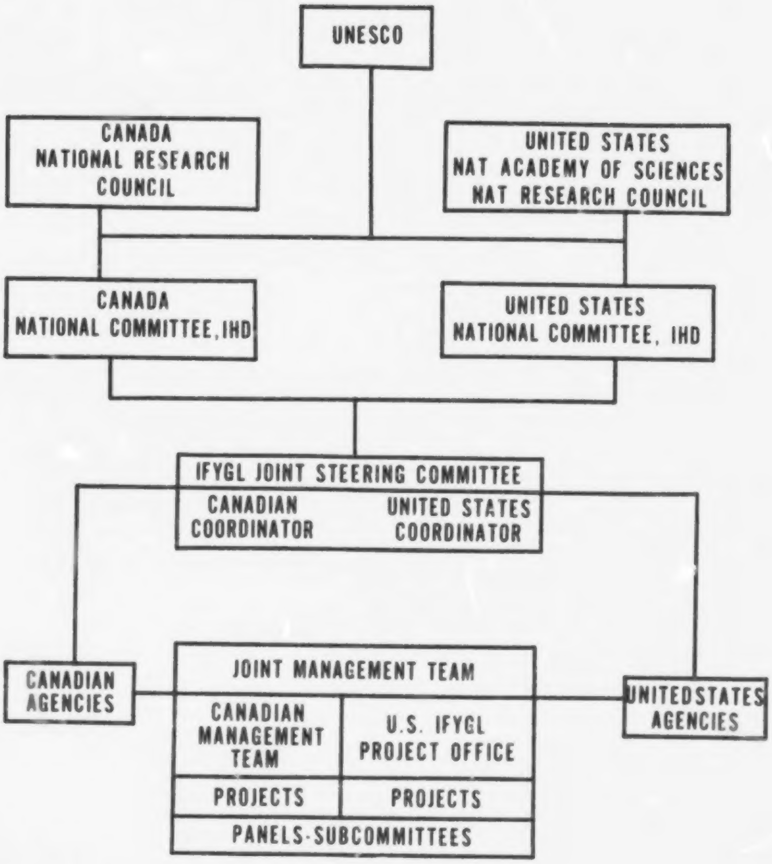
UNESCO
CANADA NATIONAL RESEARCH COUNCIL
UNITED STATES NAT ACADEMY OF SCIENCES NAT RESEARCH COUNCIL
CANADA NATIONAL COMMITTEE, IHD
UNITED STATES NATIONAL COMMITTEE, IHD
IFYGL JOINT STEERING COMMITTEE
CANADIAN COORDINATOR
UNITED STATES COORDINATOR
CANADIAN AGENCIES
JOINT MANAGEMENT TEAM
CANADIAN MANAGEMENT TEAM
U.S. IFYGL PROJECT OFFICE
PROJECTS
PROJECTS
PANELS-SUBCOMMITTEES
UNITEDSTATES AGENCIES

Figure 1: International coordination of IFYGL.

PROGRAM APPROACH

IFYGL Schedule and Technical Plan

An outline of the U.S. schedule for IFYGL is given in Figure 2, which shows the phasing of six major activities over a six-year period. The present schedule for the field operations, April 1, 1972, to March 31, 1973, is the third to be selected internationally, and was agreed upon in April 1971 by R. M. White, NOAA, and R. F. Shaw, Environment Canada. Not reflected in Figure 2 is the fact that the planning began some six years ago in 1966. The results of the past many years of work by the Steering Committee, the

Table 1: U.S. agencies participating in IFYGL

Department or Agency	Unit
Department of Commerce	National Oceanic and Atmospheric Administration
Department of Defense	Air Force: Air Weather Service Army: Corps of Engineers
Department of Interior	Bureau of Sports Fisheries: Great Lakes Fisheries Laboratory Geological Survey
Department of Transportation	Coast Guard Federal Aviation Agency
Environmental Protection Agency	
National Aeronautics and Space Administration	Earth Observation Programs (ERTS Satellite)
National Science Foundation	
New York State Department of Environmental Conservation	

Table 2: U.S. private participating institutions

- Beaukers Laboratories
- Cape Fear Technical Institute
- Center for the Environment and Man
- Cornell Aeronautical Laboratory
- General Electric
- Manhattan College
- National Center for Atmospheric Research
- State University of New York
- Texas Instruments, Inc.
- University of Miami
- University of Michigan
- University of Nevada
- University of Rochester
- University of Washington
- University of Wisconsin

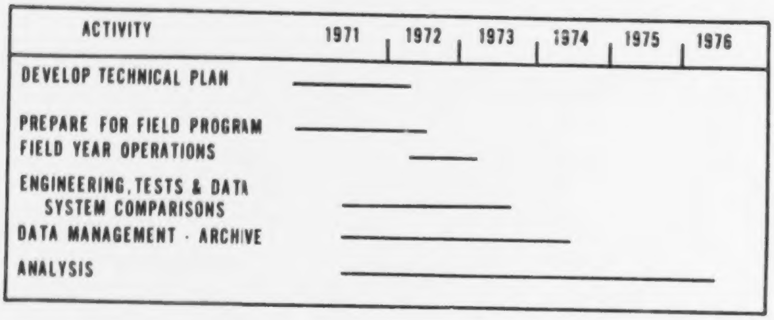

Figure 2: U.S. IFYGL schedule.

Table 3: IFYGL technical plan

Volume	Title	Contents
1	Scientific Program	projects, objectives, products, approach
2	Data Acquisition Systems	systems, elements, characteristics, deployment
3	Field Operations Plan	detailed observational procedures, schedules
4	Data Management Plan	policies, procedures, facilities, data products, schedules

scientific panels and subcommittees and the two McMaster University workshops have now been brought into focus by the IFYGL Technical Plan, a four-volume compendium issued in April 1972 (Table 3). In accordance with a decision by the Joint Management Team, a draft plan was prepared, and the Washington Workshop convened in January 1972 resulted in a more complete version of the Plan. Future updates will be handled on an ad hoc basis.

Scientific Program

As shown in Table 3, Volume 1 of the Technical Plan contains a description of the United States and Canadian scientific programs. Some parts of these programs are internationally highly interdependent, others largely independent. The U.S. IFYGL scientific activities have been structured into three water resource management areas, eight projects, and 70 tasks. The interrelationships among the three areas is shown in Table 4. For further details, the reader is referred to the Technical Plan and to IFYGL Bulletin Nos. 1, 3, and 4.

Table 4: Tasks, projects, and water resources management problem areas

	PROJECTS	1. TERRESTRIAL WATER BALANCE	2. ATMOSPHERIC WATER BALANCE	3. EVAPORATION SYNTHESIS	4. LAKE HEAT BALANCE	5. LAKE CHEMISTRY AND BIOLOGY	6. WATER MOVEMENT	7. ATMOSPHERIC BOUNDARY LAYER	8. SIMULATION
SYNTHESIS PROGRAM	WATER QUALITY	X			X	X	X	X	X
	WATER QUANTITY	X	X	X			X	X	X
	OTHER ENVIRONMENTALLY SENSITIVE OPERATIONS		X		X		X	X	X
TASKS	1. Phosphorus sediments					X			
	2. Net radiation				X	X	X		
	3. RFF/DC-6 boundary layer fluxes			X				X	
	4. Nitrogen fixation					X			
	5. Mentor buoys and towers							X	
	6. Fish populations					X			
	7. Materials balance					X			
	8. Runoff	X				X			
	9. Evaporation–terrestrial water balance	X		X					
	10. Terrestrial water balance analysis	X							
	11. Land precipitation	X							
	12. Transport in Rochester Embayment					X			
	13. Soil moisture and snow hydrology	X							
	14. Mesoscale circulation							X	
	15. Mesoscale simulation							X	X
	16. Lake level transfer	X							
	17. Near-shore ice				X		X		
	18. Advection term-energy balance				X				
	19. Genesee materials balance					X			
	20. Boundary layer flux synthesis			X				X	
	21. Hazardous material flow					X			
	22. Chlorophyll-lidar measurements					X			

	PROJECTS	1. TERRESTRIAL WATER BALANCE	2. ATMOSPHERIC WATER BALANCE	3. EVAPORATION SYNTHESIS	4. LAKE HEAT BALANCE	5. LAKE CHEMISTRY AND BIOLOGY	6. WATER MOVEMENT	7. ATMOSPHERIC BOUNDARY LAYER	8. SIMULATION
SYNTHESIS PROGRAM	WATER QUALITY	X			X	X	X	X	X
	WATER QUANTITY	X	X	X			X	X	X
	OTHER ENVIRONMENTALLY SENSITIVE OPERATIONS		X		X		X	X	X
TASKS	23. Terrestrial water balance–inflow/outflow	X							
	24. Flow model	X							
	25. Radiation, temperature, & water vapor profiles							X	
	26. Algal nutrient studies					X			
	27. Wave studies						X		
	28. Cloud climatology		X		X				
	29. Zooplankton production					X			
	30. Terrestrial water balance–lake storage	X							
	31. Terrestrial water balance–soil moisture	X							
	32. Lake levels model	X							
	33. Eastern near shore					X			
	34. Internal waves						X		
	35. *Pontoporeia affinis* and other benthos					X			
	36. Pan evaporation			X					
	37. Water movements						X		X
	38. Tower program							X	
	39. Airborne snow reconnaissance	X							
	40. Optical properties				X				
	41. Storage term–energy balance				X				
	42. Sensible and latent heat flux				X				
	43. Thermal characteristics and advection						X		
	44. Oswego harbor studies					X			
	45. Remote sensing–standing water	X							
	46. Remote sensing–*Cladophora*					X			

	PROJECTS	1. TERRESTRIAL WATER BALANCE	2. ATMOSPHERIC WATER BALANCE	3. EVAPORATION SYNTHESIS	4. LAKE HEAT BALANCE	5. LAKE CHEMISTRY AND BIOLOGY	6. WATER MOVEMENT	7. ATMOSPHERIC BOUNDARY LAYER	8. SIMULATION
SYNTHESIS PROGRAM	WATER QUALITY	X			X	X	X	X	X
	WATER QUANTITY	X	X	X			X	X	X
	OTHER ENVIRONMENTALLY SENSITIVE OPERATIONS		X		X		X	X	X
TASKS	47. Remote sensing--suspended sediments						X		
	48. Island/land precipitation	X							
	49. Lake circulation						X		X
	50. Atmospheric water balance		X						
	51. Evaporation synthesis			X					
	52. Terrestrial water balance groundwater flux and storage	X							
	53. Spring algal blooms					X			
	54. Ice studies				X				
	55. Langrangian current observations						X		
	56. Lake circulation						X		
	57. Phytoplankton nutrient bioassays					X			
	58. Terrestrial water balance–runoff	X							
	59. Coastal chains						X		
	60. Phytoplankton					X			
	61. Satellites–cloud, ice, and surface temperatures		X		X		X		
	62. Western near-shore biology and chemistry					X			
	63. NCAR/DRI Buffalo program							X	
	64. Eutrophication modeling								X
	65. *Cladophora* nutrient bioassay					X			
	66. Sediment oxygen demand					X			

		PROJECTS	1. TERRESTRIAL WATER BALANCE	2. ATMOSPHERIC WATER BALANCE	3. EVAPORATION SYNTHESIS	4. LAKE HEAT BALANCE	5. LAKE CHEMISTRY AND BIOLOGY	6. WATER MOVEMENT	7. ATMOSPHERIC BOUNDARY LAYER	8. SIMULATION
SYNTHESIS PROGRAM	WATER QUALITY		X			X	X	X	X	X
	WATER QUANTITY		X	X	X			X	X	X
	OTHER ENVIRONMENTALLY SENSITIVE OPERATIONS			X		X		X	X	X
TASKS	67.	Main lake macrobenthos					X			
	68.	Hazardous chemicals					X			
	69.	Basin precipitation—land and lake	X	X						
	70.	Evaluation of ERTS data	X							

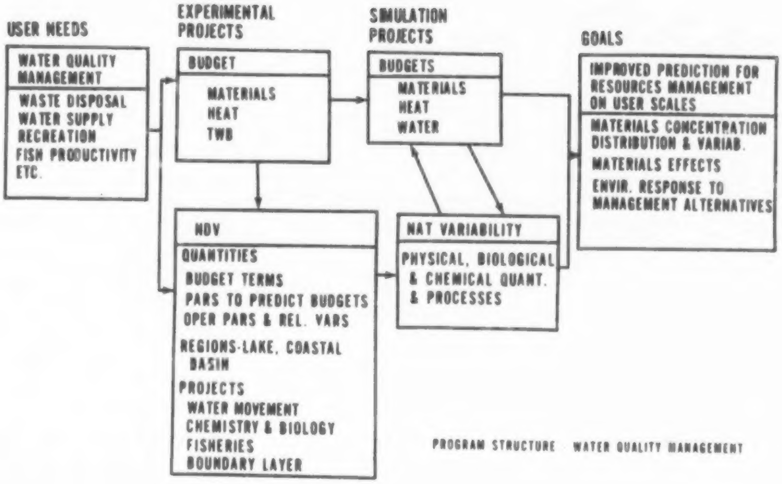
USER NEEDS
WATER QUALITY MANAGEMENT
WASTE DISPOSAL
WATER SUPPLY
RECREATION
FISH PRODUCTIVITY
ETC.
EXPERIMENTAL PROJECTS
BUDGET
MATERIALS
HEAT
TWB
NDV
QUANTITIES
BUDGET TERMS
PARS TO PREDICT BUDGETS
OPER PARS & REL. VARS
REGIONS-LAKE, COASTAL BASIN
PROJECTS
WATER MOVEMENT
CHEMISTRY & BIOLOGY
FISHERIES
BOUNDARY LAYER
SIMULATION PROJECTS
BUDGETS
MATERIALS
HEAT
WATER
NAT VARIABILITY
PHYSICAL, BIOLOGICAL & CHEMICAL QUANT. & PROCESSES
GOALS
IMPROVED PREDICTION FOR RESOURCES MANAGEMENT ON USER SCALES
MATERIALS CONCENTRATION DISTRIBUTION & VARIAB.
MATERIALS EFFECTS
ENVIR. RESPONSE TO MANAGEMENT ALTERNATIVES
PROGRAM STRUCTURE WATER QUALITY MANAGEMENT

Figure 3: IFYGL program structure pertaining to water quality objectives.

An overview of the IFYGL program structure in support of water quality management is presented in Figure 3. A similar structure is applicable to both the program in support of water quantity management and that to support management of environmentally sensitive operations. The structure shows the progression from definition of user needs in terms of waste disposal, water supply, recreation, etc., through experimental projects and simulation projects, to prediction of consequences of alternative management decisions.

Experimental field projects are given major emphasis in IFYGL. These projects are being undertaken to ascertain the important large-scale spatial and temporal processes in Lake Ontario and the Ontario basin and are referred to as budget or balance projects, e.g., materials balance, heat balance, terrestrial water balance, and atmospheric water balance. The objective of the materials balance project is to determine the amounts and forms of materials entering, leaving, and residing in Lake Ontario, with emphasis on basic plant nutrients and, to a lesser extent, on heavy metals. The Lake heat balance project will determine the form, amount, and seasonal variation of heat energy entering, leaving, and stored in Lake Ontario. The terrestrial water balance project will determine the form, amount, and seasonal variation of water entering, leaving, and stored in Lake Ontario and the Ontario basin. The atmospheric water balance project will determine the magnitude of the terms in the atmospheric water balance equation and their contribution to the hydrologic cycle of Lake Ontario.

Experimental projects also address small-scale natural distribution and variability (NDV) of budget terms, parameters related to the prediction of the budgets, and operational parameters and related variables. These experiments cover the entire Lake, coastal regions, and the basin. Major projects dealing with the smaller scale natural distribution and variability are water movement, chemistry and biology, fisheries, and boundary layer. The objective of the water movement project is to determine the characteristics of large-scale water motion and the processes responsible for natural distribution and variability. Studies will include analyses of physical properties, diagnostic models, simulation models of Lake and coastal circulation and diffusion, internal waves, and surface waves. The chemistry and biology project will investigate chemical and biological status and processes of the open Lake and the inshore zone as well as processes in selected tributary rivers. For a large number of chemical species, studies will describe the concentrations and distribution, and biological studies will determine the types, distributions, and amounts of phytoplankton, zooplankton and benthos. These studies also are directed toward the development of models for simulation purposes. A fisheries project is investigating the Lake Ontario fish stocks, species composition, distribution, relative abundance, growth rates, and incidence of lamprey predation. The boundary layer project will determine air-water interface fluxes of heat, moisture, and momentum and will undertake parameterization studies of the boundary layer fluxes.

A synthesis of Lake Ontario evaporation will be undertaken for biweekly or monthly periods to determine the best estimates of Lake evaportaion based upon terrestrial water balance, atmospheric water balance, and Lake heat balance estimates and on evaporation pan data and boundary layer measurements.

While the experimental approach is given major emphasis in IFYGL, water resource management requires improved prediction of the hydrological and limnological variables which impact upon the performance and costs of management alternatives. Modeling and simulation projects are therefore included in IFYGL to develop improved prediction of the limnological and hydrological characteristics of Lake Ontario and the Ontario basin for resource management purposes. The experimental projects will provide data describing the variations that take place in the Lake and basin and the scales of the temporal and spatial variability. These projects will also provide data to examine interrelationships between parameters to analyze the reasons for observed changes. The goal is to develop improved models to simulate the environment and to yield information pertinent to meaningful water resource management alternatives or "what-if" questions.

OPERATIONS AND DATA ACQUISITION

The data collection program of IFYGL is the most comprehensive yet planned for one of the Great Lakes with regard to the network intensity in space and time spanning the Lake and basin, the numbers and types of data acquisition systems, and the use of advanced data acquisition systems. Figure 4 shows some of the major U.S. IFYGL data collection systems and the data flow. The U.S. Field Headquarters, located in Rochester, New York, is responsible for the deployment, operations, maintenance, and logistic support

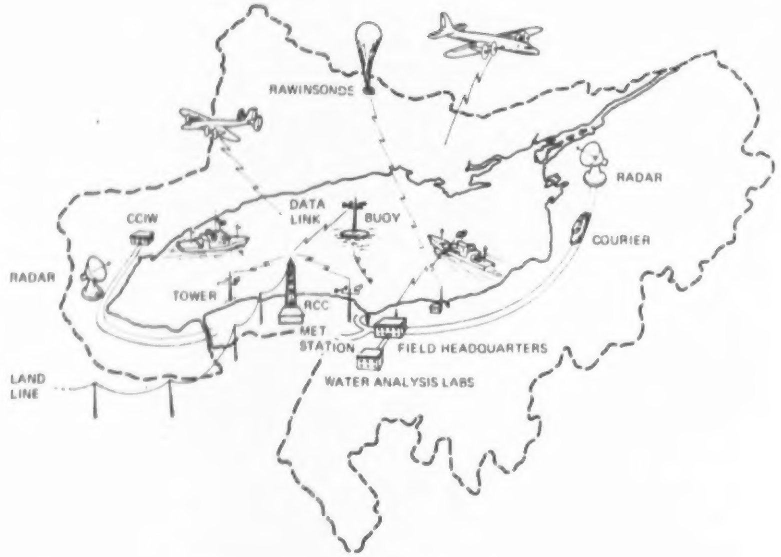

Figure 4: IFYGL data collection systems and data flow.

for the major U.S. data acquisition systems and for field data management activities. The Canada Centre for Inland Waters (CCIW) is the focal point for Canadian field operations. From some of the five acquisition systems identified in Figure 4, data are communicated automatically, while from others data must be retrieved manually by courier.

The ship systems measure the physical, chemical, biological, and meteorological properties of the Lake and atmosphere at predetermined stations and along tracks using an accurate DECCA navigation system and various measurement devices, e.g., electronic BT. Water samples are obtained and processed at water analysis laboratories on board the vessels and also at shore facilities. Canada has three major research vessels participating in data collection, the *Martin Karlsen*, the *Limnos*, the *Port Dauphine* as well as smaller vessels. The U.S. has two, the *Researcher* (Figure 5) and the *Advance II*, and many smaller vessels (Table 5). The sampling network for lake temperature and water chemistry analysis is shown in Figure 6.

The IFYGL buoy, tower, and automatic meteorological stations measure current, water temperature, water levels, and surface meteorological parameters. This network, shown in Figure 7, includes 11 Canadian and 10 U.S. buoys. The diagram in Figure 8 shows the major buoy components as well as the surface meteorological and oceanographic sensors, and a sample of a buoy eight-day time series of water temperature at four depths is presented in Figure 9. Each six-minute observation is recorded as a dot in this figure. A

Figure 5: *Researcher*

Table 5: U.S. Vessels participating in IFYGL

Name	Length (ft)	Function
Researcher	278	Lake scientific cruise
Advance II	185	Lake scientific cruise
Maple	122	Buoy tending
Shenehon	65	Lake and inshore cruise
Oswego T-boat	65	Inshore scientific cruise
Dambach	65	Inshore scientific cruise
Kaho	65	Fisheries
Johnson	58	Buoy tending
N-Small boats	17-30	Inshore scientific cruise and buoy tending

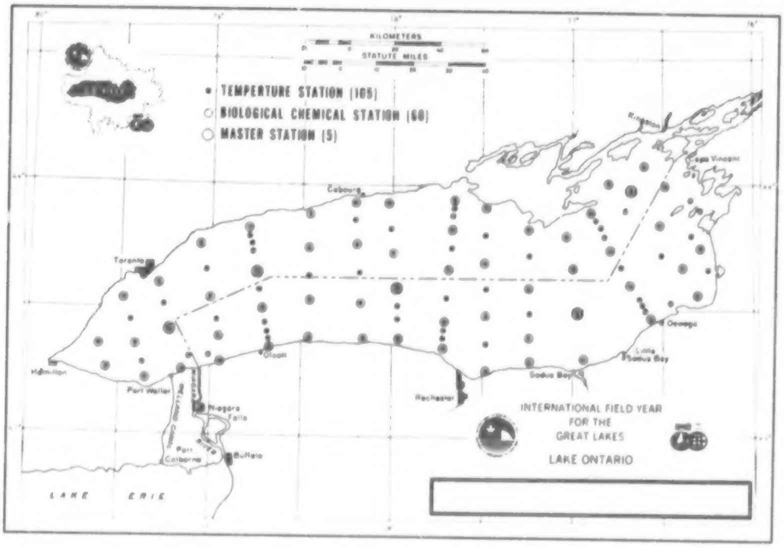
KILOMETERS
STATUTE MILES
• TEMPERTURE STATION (105)
○ BIOLOGICAL CHEMICAL STATION (60)
○ MASTER STATION (5)
Kingston
Cape Vincent
Cobourg
Toronto
Hamilton
Port Weller
Olcott
Niagara Falls
Port Colborne
Buffalo
Rochester
Sodus Bay
Little Sodus Bay
Oswego
INTERNATIONAL FIELD YEAR
FOR THE
GREAT LAKES
LAKE ONTARIO
LAKE ERIE

Figure 6: Lake scale water sampling network.

IFYGL OBSERVATION SYSTEM

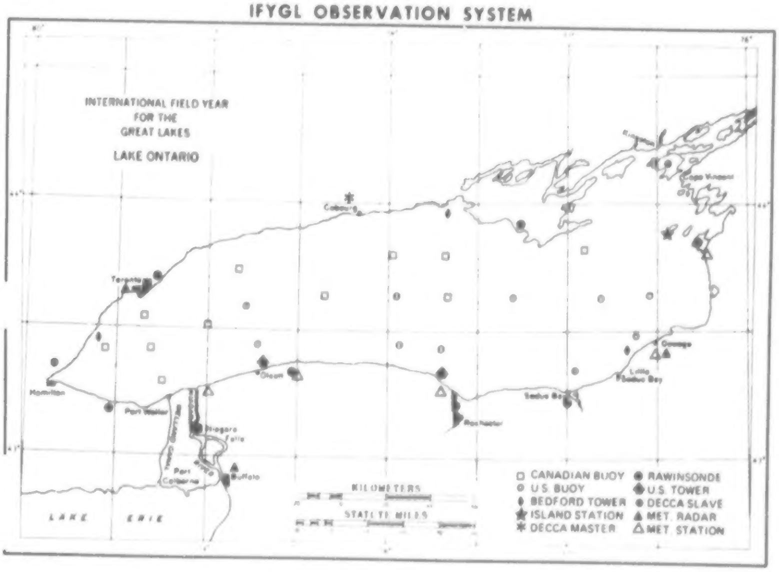
INTERNATIONAL FIELD YEAR
FOR THE
GREAT LAKES
LAKE ONTARIO
Kingston
Cape Vincent
Cobourg
Toronto
Hamilton
Port Weller
Olcott
Niagara Falls
Port Colborne
Buffalo
Rochester
Sodus Bay
Little Sodus Bay
Oswego
LAKE ERIE
KILOMETERS
STATUTE MILES
□ CANADIAN BUOY
⊙ U.S. BUOY
♦ BEDFORD TOWER
★ ISLAND STATION
✱ DECCA MASTER
● RAWINSONDE
◆ U.S. TOWER
● DECCA SLAVE
▲ MET. RADAR
△ MET. STATION

Figure 7: IFYGL network of buoys, towers and land stations.

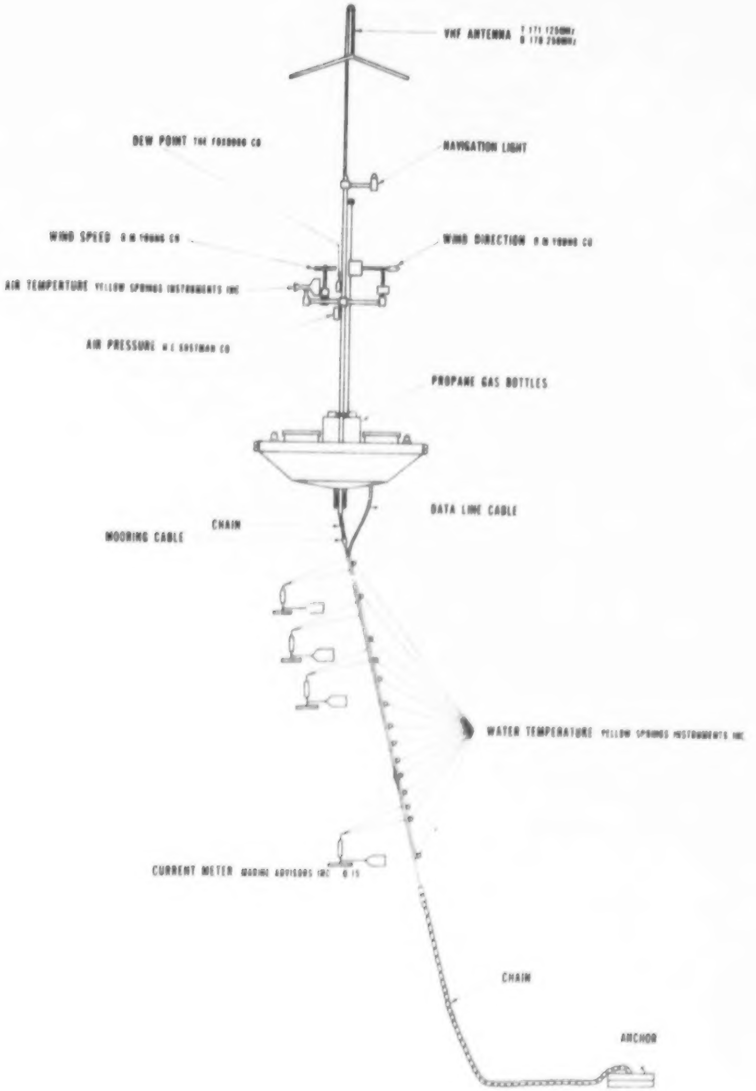
VHF ANTENNA T 171 125MHz R 170 250MHz
DEW POINT THE FOXBORO CO
NAVIGATION LIGHT
WIND SPEED R M YOUNG CO
WIND DIRECTION R M YOUNG CO
AIR TEMPERTURE YELLOW SPRINGS INSTRUMENTS INC
AIR PRESSURE H E SOSTMAN CO
PROPANE GAS BOTTLES
DATA LINE CABLE
CHAIN
MOORING CABLE
WATER TEMPERATURE YELLOW SPRINGS INSTRUMENTS INC
CURRENT METER MARINE ADVISORS INC Q 15
CHAIN
ANCHOR

Figure 8: A U.S. IFYGL buoy.

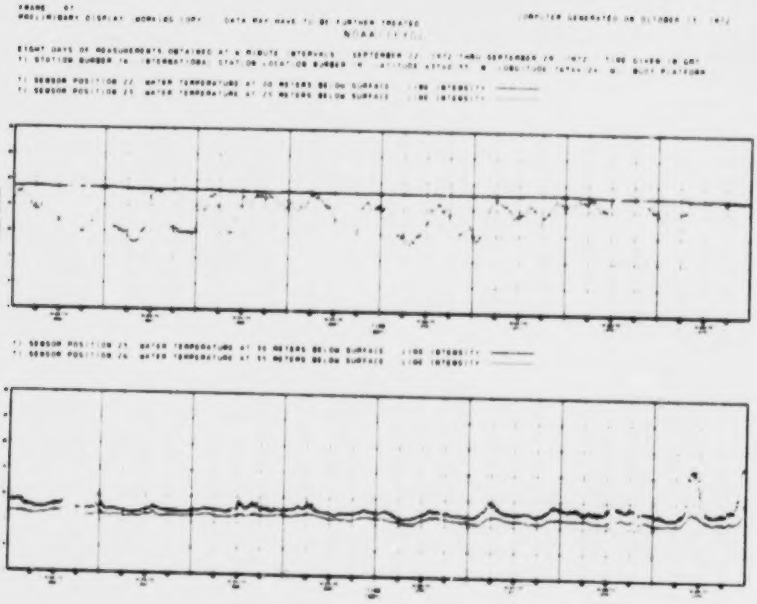

Figure 9: Sample of "quick look" graphics from a U.S. buoy.

rather sharp thermocline exists between 20 and 30 meters. Internal waves are apparent at the 25-meter level temperature record, with periods that approximate the inertial period for the latitude of Lake Ontario, 17 hours.

Two U.S. and one Canadian weather radars are making routine observations and with proper calibration measure precipitation intensity for small areas and time elements. The two U.S. radars make measurements over areas of 2° of arc by one-mile radial increment and span Lake Ontario and the basin every 10 minutes for the 12-month field year. The radar echo intensity is automatically digitized and recorded on magnetic tape for subsequent data processing. Precipitation observations are obtained from the conventional climatological network within the basin. A special rainfall network is deployed and operated south of Rochester, a special snowfall network in the eastern part of the basin. These precipitation observations will be used to calibrate and test the radar, storm by storm, as a precipitation-measuring data acquisition system.

Advanced rawinsonde systems are being operated from three United States and three Canadian stations around the Lake. More precise wind measurements result from the Loran C navigation receiver on the sonde than are achieved by conventional rawinsondes used by weather services. More frequent time commutation switching gives more precise profile measurements of temperature and relative humidity versus pressure.

Aircraft are being used to measure vertical fluxes of heat, moisture, and momentum in the atmospheric boundary layer and to make meteorological observations of temperature, dew point, and wind velocity. Other aircraft remotely sense surface temperature and snowpack water content and make multispectral and radiation measurements. Aircraft participating in IFYGL are listed in Table 6. Many other data collection systems are used by participating scientists, e.g., towers, wells, and stream gauges. Measurements include species and concentrations of fish, benthos, phytoplankton, and zooplankton.

DATA MANAGEMENT

All IFYGL data collections will be submitted to the United States and Canadian data centers in a timely manner, and there will be complete international data exchange. As shown in Figure 2, the data management activity overlaps the Field Year, but continues well into 1974.

The U.S. IFYGL Data Center, NOAA, is responsible for the management of coordination of all IFYGL data, i.e., data collected by U.S. investigators and copies of all Canadian data. U.S. data will be stored in more than one data center. Data pertaining to physical parameters will be stored in the Great Lakes Data Center of the Environmental Data Service, NOAA. Biological and chemical data will be stored in the Environmental Protection Agency's Storet system.

The data centers will maintain an IFYGL data catalogue, summarized data, quality-controlled and documented processed data, and raw data. Processed data will comprise the largest part of the data bank and will consist of data collected by the agencies, translated, checked, and verified. The data management philosophy is to make all IFYGL data, data products, and data support information available to any interested persons as easily and as inexpensively as possible.

Table 6: U.S. aircraft participating in IFYGL

Type	Program
DC-6-39C	Boundary layer
DC-6-40C	Boundary layer
Buffalo	Boundary layer
Queen Air	Boundary layer
C-46	Remote sensing
C-47	Remote sensing
Aztec "C"	Remote sensing
CV 990	Remote sensing
Cessna	Remote sensing

DATA ANALYSIS AND EXPECTED RESULTS

The U.S. analysis activity will continue some three years beyond the termination of Field Year operations (Figure 2). The IFYGL data collection will be used to calculate the large scale budgets and to define the natural distribution and variability that takes place in the Lake and basin. To the extent feasible, this data collection will also be used to explain natural distributions and variability and to develop models of interactive processes.

The one-year data base scheduled for IFYGL limits the types of analyses that can be performed. There are significant year-to-year meteorological, hydrological, and limnological variations. Such long-period variability is beyond the scope of IFYGL. Likewise, for some hydrologic purposes, the rare event, e.g., a flood, is of most significance, and data records for many years are required to establish the climatology of such events and to develop statistically stable prediction techniques. Because the IFYGL data record is short, attention will be focused on short-period fluctuations and the theoretical modeling approach. Additional data collection may be necessary to develop the interrelationships between parameters required for simulation models. The design of future data collections, however, should be based upon the results drawn from IFYGL concerning the natural distribution and variability of parameters.

Major results expected from future IFYGL analyses include the following:

(1) detailed analysis of large-scale processes relative to Lake Ontario and the basin. Included are the terrestrial water balance, Lake heat balance, atmospheric water and heat balance, and materials balance of the Lake and selected tributaries.

(2) analysis of the natural distribution and variability of a variety of physical quantities, (e.g., budget terms), parameters, (e.g., lake currents and temperature), and phenomena, (e.g., internal waves, surface waves, thermal bar, and lake-scale circulation).

(3) detailed case studies for periods of special interest relating to the lake-atmosphere system.

(4) analysis of the natural distribution and variability of chemical concentrations and processes including conservative chemicals, (e.g., chloride) and nonconservative properties of ecological interest (e.g., nutrients) and analysis of interdependencies and processes related to features of observed variability.

(5) analysis of the natural distribution and variability of selected biological properties, (e.g., chlorophyll, zooplankton, biomass, major plankton species, particle counts), and analysis of interdependencies and processes related to features of observed variability.

(6) models for analysis, diagnosis, prediction, and simulation of physical, chemical, and biological natural distributions and variability and analysis of alternatives pertinent to water resource management.

A series of scientific reports is anticipated. The first several of the reports will, on the United States side, consist of detailed descriptions of the acquisition systems. Later, as scientific analyses progress, results will be disseminated in the same series.

CONCLUSIONS

International coordination runs throughout IFYGL with respect to organization, management, planning, field operations, data management, analysis, and documentation of results. The scientific program and supporting data collections described are ambitious. IFYGL has a challenging central objective, i.e., to strengthen knowledge of Lake Ontario and the Ontario basin in order to provide a scientific basis for improved Great Lakes management pertaining to water quantity and water quality, and environmentally sensitive operations dealing with land and water use. While the one-year data collection period may prove insufficient for some purposes, products meaningful to Great Lakes management will result from this effort.

Environmental Data and Information Services in the Great Lakes

Christopher D. Noe, Chief, Special Projects, National Oceanic and Atmospheric Administration, National Oceanographic Data Center, Department of Commerce

ABSTRACT

NOAA operates national centers for archiving, retrieving and disseminating environmental data in the atmospheric, marine and solid earth disciplines. Within NOAA's overall mission, this responsibility rests with the Environmental Data Service (EDS). Present efforts in the Great Lakes include preparing an inventory of available historical environmental data in the Lakes, archiving a complete set of IFYGL data, and creating the Great Lakes Data Center (GLDC). The GLDC will be located in the Lakes area and will provide access to both historical and contemporary data files for use by federal agencies, industry, private research organizations and the general public.

* * *

Within the National Oceanic and Atmospheric Agency's (NOAA) mission lies a responsibility for acquiring, processing, storing, and disseminating large quantities of environmental data. In the Great Lakes area, these responsibilities have in the past been relegated to the agency acquiring the data. This practice imposes something of a hardship on these agencies in that they are neither funded nor staffed for long-term or frequent data service functions.

In February of this year, the Environmental Data Service (EDS) of NOAA established a special unit within the National Oceanographic Data Center (NODC), Washington, D.C., to meet the needs of multidisciplinary data users in the Great Lakes and Great Lakes drainage area. Present plans call for this unit to evolve into a Great Lakes Data Center (GLDC) and open its doors (probably here in Ann Arbor) in early fiscal year 1974. This center will serve as a focus within the EDS for functions presently handled by the National Oceanographic Data Center, the National Climatic Center (NCC), and the National Geophysical and Solar-Terrestrial Data Center (NGSDC). In addition, the Great Lakes Data Center will centralize and provide access to environmental data files or referral inventories from academic and research institutions and industry. All of these contributors will benefit in that they will have the GLDC as a single access point for their own data requirements.

One of the first tasks of the GLDC will be to serve as the U.S. National Repository for a complete set of the data generated by both the United States and Canada during IFYGL. These data will first undergo preliminary data reduction, quality control and analysis by Canada, the IFYGL analysis group, and the Center for Experimental Design and Data Analysis (CEDDA), another EDS component.

As a prerequisite to archiving the IFYGL data, EDS has established an automated "Data Catalog," an inventory containing over 3600 records of data collection efforts of both countries. Although primarily designed for U.S. and Canadian data managers for IFYGL, the listing is available to any user interested in environmental data for the Great Lakes area.

Another NOAA project being undertaken by EDS is the Environmental Data Index (ENDEX). The general goal of ENDEX is to establish an interactive retrieval system containing searchable descriptions of files of environmental data as well as detailed inventories of readily available data files. This system will provide researchers, commissions, planners, ecologists and other environmental scientists in government and non-government organizations with an effective, convenient referral to existing files of environmental data. Completion date for this national project is 1978, at a cost of approximately 8 million dollars, although many practical advantages will accrue earlier.

The ENDEX project is of interest to this meeting because the Great Lakes Basin has been selected for one of the priority pilot studies. Contracts are being negotiated with the University of Michigan, University of Wisconsin, and State University of New York to inventory historical and current data files containing Great Lakes environmental data. A separate effort will be made to inventory Canadian data, hopefully on an exchange basis.

When the Great Lakes portion of ENDEX is completed, GLDC will have an invaluable tool both for referral of users to data sources and for reviewing historical files as to suitability for selective accessioning. Historical files having large quantities of data and wide usage by the scientific community will be accessioned first and, where feasible, processed into standard formats. Some data files will not be accessioned at all, but will remain in the ENDEX referral system. A parallel system, the Oceanic and Atmospheric Science Information System (OASIS), is being designed by EDS to provide specialized literature references which will complement the ENDEX information.

Another type of data and information service performed by the NOAA for the Great Lakes is the Great Lakes Observing Program. This effort includes about 40 U.S. lake carriers making meteorological observations every six hours while underway. Special observations are made when conditions warrant. In addition, a network of coastal stations (mostly U.S. Coast Guard) take measurements at synoptic times. A total of about 15,000 observations have been taken each year in the EDS publication *Mariners' Weather Log*. This publication also carries annual summaries of the Great Lakes navigation season.

Also, of great value to those interested in data and information on the Great Lakes are NOAA's state climatologists. As an example of the value of their background and local knowledge, one can cite the publication *The Climate of the Great Lakes Basin*, which is published by the Canadian

Atmospheric Environment Service. The U.S. state climatologists were selected for the technical review.

The final NOAA source of data for the Great Lakes that I will mention is the Lake Survey Center. I will not go into detail as this group is giving several presentations today, but it should be noted that they have extensive lake environmental data collections for their research and charting efforts. Their principal files contain historical lake level data dating back more than a century, but they also maintain files on surface and subsurface currents, ice formation and breakup, and lake chemistry.

In summary, expanded data and information services in the Great Lakes are beginning to crystallize around NOAA's Great Lakes Special Project and the Environmental Data Index. In a very short time there will be a central focus for data and referral services for both federal and non-federal agency needs.

Great Lakes Environmental Monitoring and Prediction Services of the National Weather Service

Max W. Mull, National Weather Service, National Oceanic and Atmospheric Administration, Department of Commerce

The National Weather Service (NWS) provides warnings and forecasts of wind, weather, waves, storm surge, and ice cover for the Great Lakes and surrounding area as part of its national responsibilities. A complex organization exists, encompassing data collection, the processing of data into service products, and delivery of the forecasts and warnings to the marine users. Principal customers for marine services are those involved in commercial shipping and in recreational boating and fishing.

Guidance on major storm and weather systems is supplied by the National Meteorological Center at Suitland, Maryland. Focal point for information on severe storms over the nation is our facility at Kansas City. Weather Service Forecast Offices (WSFO) at Chicago, Detroit, and Cleveland provide forecasts and warnings for the Lakes. Local marine services are provided at Weather Service Offices located in Duluth, Marquette, Sault Ste. Marie, Green Bay, Milwaukee, Grand Rapids, Muskegon, Alpena, Toledo, Erie, Buffalo, and Rochester (Figure 1). The forecast office at Detroit coordinates the National Weather Service Great Lakes ice program.

The NWS manages a cooperative marine observation program on about 45 of the Great Lakes carriers. Canada has a similar program. In addition, there are numerous weather observation stations around the Lakes, most of them operated by the Coast Guard, from which reports are received several times daily. All data are shared with Canada (Figure 2).

Several teletypewriter and facsimile circuits are operated by the NWS to receive data and guidance and to send out the prepared forecasts and warnings.

In addition to the Weather Wire, which is a teletypewriter circuit connecting major commercial radio, TV, and daily newspapers, the NWS operates a network of VHF-FM continuous broadcast stations. In the Great Lakes area, stations are located at Cleveland, Chicago, Detroit, Milwaukee, Sandusky, and Buffalo. Mariners on the Lakes are also reached with the cooperation of Coast Guard and commercial coast stations.

The marine program on the Great Lakes is being substantially improved through the interagency efforts and resources of the Demonstration Program to Extend the Shipping Season on the Great Lakes. In the NWS, the ice program at Detroit has been strengthened, a dedicated Great Lakes marine

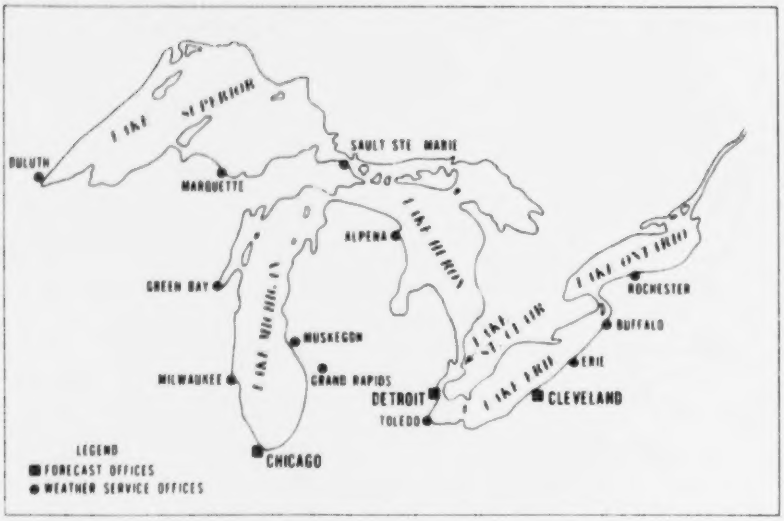
LAKE SUPERIOR
DULUTH
MARQUETTE
SAULT STE MARIE
LAKE HURON
ALPENA
LAKE MICHIGAN
GREEN BAY
MUSKEGON
GRAND RAPIDS
MILWAUKEE
CHICAGO
DETROIT
TOLEDO
LAKE ST CLAIR
LAKE ERIE
CLEVELAND
ERIE
BUFFALO
ROCHESTER
LAKE ONTARIO
LEGEND
FORECAST OFFICES
WEATHER SERVICE OFFICES

Figure 1: Great Lakes marine forecast and warning areas.

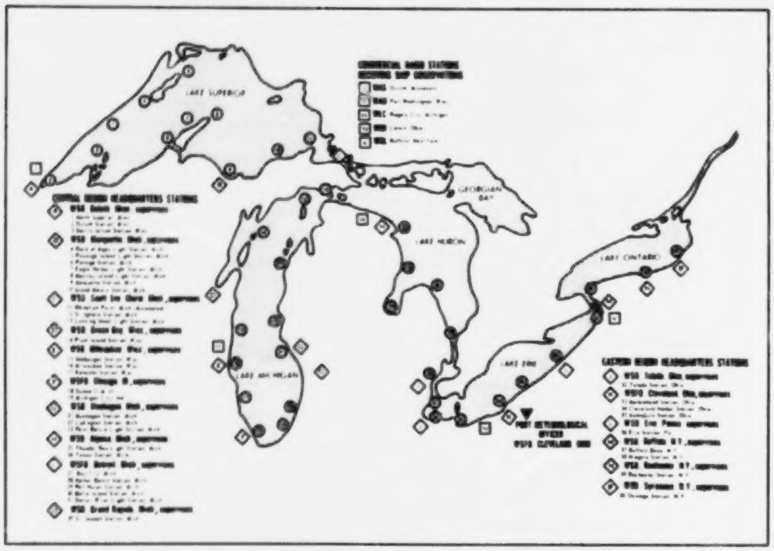
LAKE SUPERIOR
GEORGIAN BAY
LAKE HURON
LAKE MICHIGAN
LAKE ERIE
LAKE ONTARIO
CENTRAL REGION HEADQUARTERS STATIONS
EASTERN REGION HEADQUARTERS STATIONS

Figure 2: Great Lakes observing program.

Reproduced from best available copy.

teletypewriter circuit is being installed, and a NWS ice forecast specialist has been assigned to the Coast Guard operational center in Cleveland.

In addition, the National Weather Service provides forecasts of the water levels in the nation's rivers. The Kansas City and Cincinnati River Forecast Centers (RFC) are responsible for portions of the streams flowing into the Great Lakes. This responsibility is presently limited to the development of forecast procedures and the training of river district personnel, except that Cincinnati prepares forecasts for the Sandusky River in Ohio. The river district offices serving several river basins in the Great Lakes system are Grand Rapids, Lansing, Fort Wayne, Akron, Buffalo, and Rochester. WSFO, Detroit, has been assigned floor warning responsibilities for streams in the greater metropolitan area. There is a considerable portion of the Great Lakes drainage area unassigned and presently without a National Weather Service river and flood forecasting service. Extension of a formal service relates to community user requirements and national priorities when considering a national program development with limited resources.

With respect to river and flood research, the Hydrologic Research Laboratory, as part of the NWS Office of Hydrology, is the only hydrologic research laboratory in National Oceanic and Atmospheric Administration (NOAA) other than that at the Lake Survey Center. This laboratory conducts research for increased understanding of the physical processes required for prediction of water movement through the land phase of the hydrologic cycle. It also conducts and funds research on data acquisition and hydrologic forecast systems. The laboratory has conducted evaporation studies for the Great Lakes and is currently responsible for IFYGL projects pertaining to evaporation and snow cover. NWS has also proposed an IFYGL project for model simulation of the inflow to Lake Ontario.

There are two research efforts in the Marine Techniques Section of the Systems Development Office that directly support our marine services on the Great Lakes. One is the Lake Erie Storm Surge Forecast Program. This is a statistical technique which forecasts the storm surge on Lake Erie at Buffalo, New York, and Toledo, Ohio. The storm surges at Buffalo and Toledo are the departures of the Buffalo and Toledo Lake levels from their respective monthly means. Details of the method are given by Richardson and Pore (1969).[1] The storm surge technique was derived from data from 36 storm surge cases which occurred during a 30-year period. The program, which has been operational since October 1969, uses the sea-level pressure as forecast by the primitive equation (PE) model to make storm surge forecasts on Lake Erie. The output from the program is a teletype message which is transmitted on the RAWARC Circuit. An example is shown in Figure 3. The verification of the forecasts will continue to serve as a basis to modify and improve the Lake Erie Storm Surge Forecast Program.

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[1] W.S. Richardson and N. A. Pore, "A Lake Erie Storm Surge Forecasting Technique," ESSA Technical Memorandum WBTM-TDL 24, August 1969, 23 pp.

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FZUS1 KWBC 031200
LAKE ERIE STORM SURGE FORECAST 00 HR LAG
BUFFALO MAX 09 MIN -18 TOLEDO MAX 17 MIN -10
Time  Buffalo Toledo Time  Buffalo Toledo Time  Buffalo Toledo
GMT   Surge   Surge  GMT   Surge   Surge  GMT   Surge   Surge
13     06            05    -07            21    -15
14     02     -10    06    -05     -00    22    -18      17
15     02            07     02            23    -16
16    -04     -08    08    -04      07    00    -14      10
17    -04            09    -08            01    -05
18    -03     -07    10    -13      08    02    -09      13
19     09            11    -14            03    -13
20     03     -05    12    -13      08    04    -14      13
21     01            13     01            05    -15
22    -04     -07    14    -05      10    06    -14      07
23    -08            15    -09            07    -07
00    -08     -03    16    -11      08    08    -09      13
01     04            17    -13            09    -13
02    -01      01    18    -11      06    10    -12      13
03    -03            19    -06            11    -12
04    -06      01    20    -11      15    12    -10      05
```

The date-time group of the first line indicates the date and time of the initial date; the time will be either 00Z or 12Z.

The maximum and minimum values are the highest and lowest forecasts, expressed in tenths of feet, during the 48-hour period following initial time. For Buffalo there are 48 values of expected storm surge, expressed in tenths of feet, one for each hour following initial time out to 48 hours. For Toledo a forecast is made for every second hour. Therefore, the 24 values are storm surge forecasts, expressed in tenths of feet, for +2, +4, +6, --- +48 hours after initial time.

Figure 3.

The other research effort is concerned with forecasts of wind over the Great Lakes. The forecasting of winds on the Great Lakes has been approached using a statistical method to develop wind forecast equations. The equations were developed for two seasons, winter and summer. For each of the seasons there are two sets of equations, consisting of forecasts of total wind speed and the U and V wind components, at 6, 12, 18, and 36 hours. The U and V components are used to forecast the wind direction. One set requires input from the 00Z PE model while the other uses input from the 12Z PE. These equations are general in nature so that they are used to forecast the winds at all of the locations shown in the accompanying Figure 4. The wind that is forecast represents the maximum wind to be expected at a given location at a given time.

Forecasts of wind, weather, and sea, and warnings of hazardous conditions, have proved useful to mariners and recreational boatmen on the Lakes. In

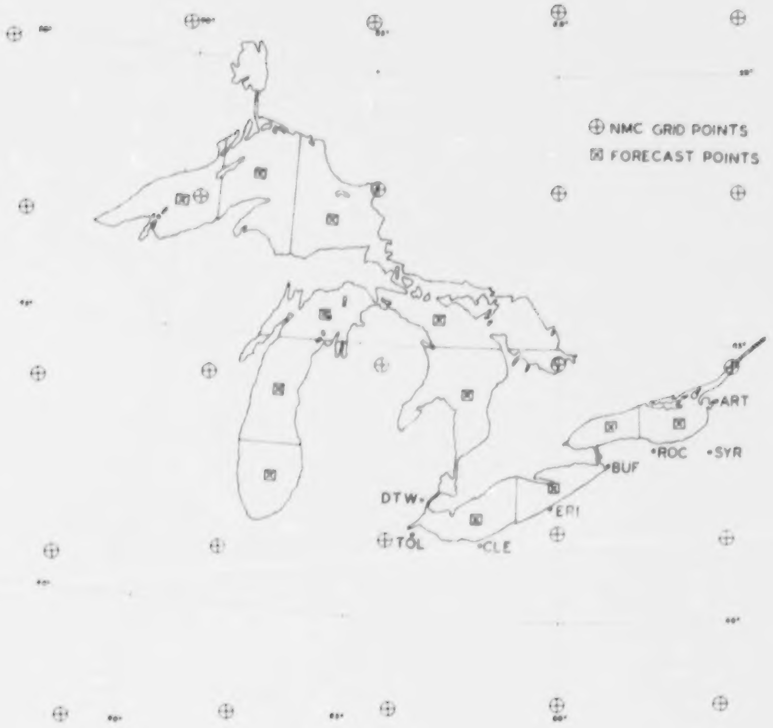


Figure 4: Wind forecast points.

common with perhaps all prediction products, however, they could provide a greater service if the accuracy were improved, and the forecast and warning lead times lengthened.

Forecasts make use of an analysis of present conditions and are limited by the adequacy of the data net on which the analyses are based. Within the Great Lakes there is a need for additional data points on the Lakes and at certain points along the shore. In addition, forecasts are limited by the available forecast techniques. On the Great Lakes additional work is needed on the response of waves to the wind stress. Also, better methods for predicting ice on the Lakes and connecting channels are needed. Work is being sponsored by the Demonstration Program on this subject.

Environmental Monitoring of the Great Lakes From Space

E. Paul McClain, National Oceanic and Atmospheric Administration, Department of Commerce

ABSTRACT

The National Environmental Satellite Service of NOAA conducts research in the area of oceanographic and hydrologic applications of Earth satellite data through its Environmental Sciences Group. Although the data used in this research are acquired chiefly from NOAA's own operational environmental satellites, observations from NASA's Nimbus, Applications Technology, and Earth Resources Technology satellites have been used extensively also. The measurements from the recently launched NOAA-2 and ERTS-1 satellites are much more useful than those from previous spacecraft for studies in areas like the Great Lakes because of the higher spatial and spectral resolution of these new data. ESG's research in the Great Lakes area includes the development of satellite data display and analysis techniques for monitoring surface temperature fields, ice cover conditions, circulation patterns, and Basin snow cover. Part of this work is being done in connection with the IFYGL.

* * *

The National Environmental Satellite Service (NESS) of NOAA performs research on oceanographic and hydrologic applications of Earth satellite data. This research, which is partly in-house and partly through contracts, is conducted by oceanographers, hydrologists, and meteorologists in NESS's Environmental Sciences Group (ESG) and Spacecraft Oceanography (SPOC) Group. The total effort over the past several years has been funded at a level near 1.5 million dollars per year, and through fiscal year 1972 this support mostly has come from NASA through transfer of funds to NOAA and the U.S. Navy (the SPOC Project transferred from the Navy to NOAA during the latter half of FY-72). NASA support virtually ended in FY-73, and NOAA will take over completely in FY-74, when the funding level requested is in excess of two million dollars. Although many aspects of the research carried out through ESG and SPOC—and SPOC will be using much of the new funding to supplement aerospace remote sensing for oceanography in other parts of NOAA—is directly applicable to environmental monitoring of the Great Lakes from space, only a small portion of NESS's effort is presently directed specifically to problems of the Great Lakes (i.e. $30K in FY-73 and $40K in Fy-74). This small project will be discussed later.

Although the data used in NESS's research are acquired chiefly from NOAA's own operational environmental satellites (known as ITOS, Improved Tiros Operational Satellites, the one launched in mid-October is designated NOAA-2), observations from NASA's research satellites have been used extensively also. Among these are Nimbus, Applications Technology Satellites (ATS), and Earth Resources Technology Satellite (ERTS). ITOS, Nimbus, and ERTS are sun-synchronous spacecraft in near-polar orbits at altitudes of 500 to 800 nautical miles. ATS is a geosynchronous satellite in an equatorial orbit at an altitude of about 22,000 miles. NOAA expects to launch its first geosynchronous operational environmental satellite, GOES, next fall. With the exception of one of the sensors on NOAA-2 and all the sensors on ERTS-1, the instruments carried by the satellites listed above have been oriented to meteorological use and have stressed broad, even global, coverage and relatively coarse spatial and spectral resolution. Oceanographic and hydrologic applications of these data have consequently been few and often marginal in usefulness, especially over areas as small as the Great Lakes. The instrumentation on these satellites has consisted chiefly of vidicon camera systems or scanning radiometers detecting reflected radiation in the visible spectrum around 0.5–0.7 micrometers with best ground resolution about 3 n. mi.; and detecting thermal infrared radiation in the water vapor window portions of the spectrum around 3.7–4.1 and 10.5–12.5 micrometers with best ground resolution about 5 n. mi.

NOAA-2 is the first of our operational satellites to carry a Very High Resolution Radiometer (VHRR), which features a visible (0.6–0.7 micrometers) and a thermal infrared (10.5–12.5 micrometers) channel, both having 0.5 n. mi. ground resolution at nadir. The ground coverage from a single direct-readout station is very large: a swath of the order of 1800 miles wide and 3600 miles long for the pass nearest directly overhead, and two somewhat shorter ones to the east and west of that one. Coverage is once daily in the visible and twice daily in the infrared. Readout stations are now in operation near Fairbanks, Alaska, and on the coast of Virginia, and a third one is scheduled for a site near San Francisco next spring. A short swath of data can be acquired on each pass out-of-range of the data acquisition stations by means of an on-board tape recorder, but direct readout is the primary mode of operation of the VHRR.

The first Earth Resources Technology Satellite was put into operation by NASA last July. It has been producing much high-quality, multispectral imagery from a four-channel scanning radiometer known as the MSS (a three-camera, return-beam vidicon system on board has been inoperative since shortly after launch). Two of the MSS channels are in the visible spectrum (0.5–0.6 and 0.6–0.7 micrometers) and two are in the near-, or reflective-, infrared (0.7–0.8 and 0.8–1.1 micrometers). Ground resolution is relatively high, about 100 meters, but the coverage is relatively small and infrequent, being a 100 n. mi. wide swath and a revisit cycle of 18 days.

The measurements from the VHRR on NOAA-2 and the MSS on ERTS-1 are more useful for studies in areas like the Great Lakes than the observations from previous spacecraft because of the higher spatial and spectral resolution

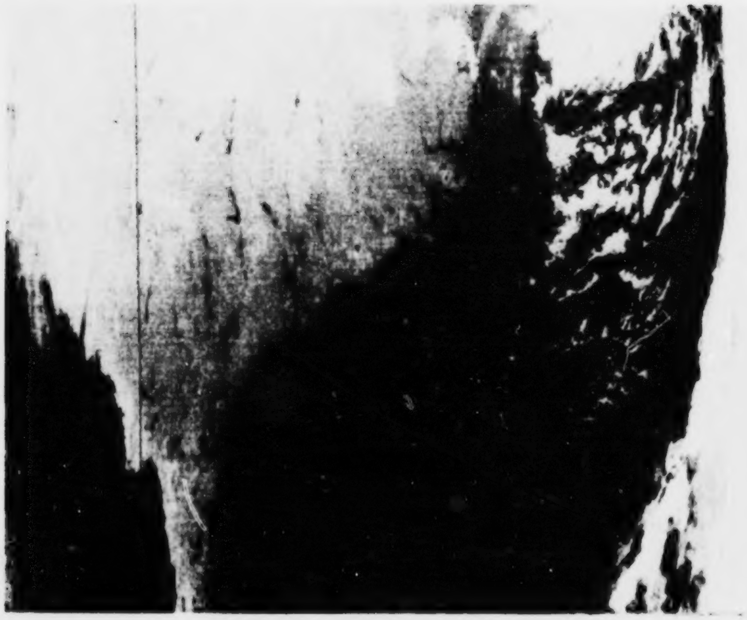


Figure 1: Thermal scanner image of Gulf Stream derived from the VHRR on the NOAA-2 satellite. The coldest surfaces in this image, such as land and clouds, appear lightest in tone, whereas the warmest water of the Gulf Stream appears darkest. The data were taken on 8 November 1972.

of these new data. ESG's research in the Great Lakes area includes development of satellite data processing, display and analysis techniques for monitoring surface temperature fields (land, water, and ice surfaces), ice cover conditions, circulation patterns, and Basin snow cover. Part of this work is being done in connection with the International Field Year for the Great Lakes (IFYGL) program.

One of ESG's IFYGL tasks is monitoring of Great Lakes water surface temperature by means of the VHRR on NOAA-2 (Figure 1). The satellite-derived infrared temperatures will be combined with those obtained by infrared radiometers carried on NOAA or other aircraft and with those obtained from ships and other means close to the Earth's surface. Another IFYGL task is a satellite survey of water color in the Great Lakes (Figure 2). NOAA-2 infrared and ERTS-1 visible and near-infrared observations are being examined to see if characteristic temperature and water color differences can be reliably determined from space. The observed spatial and temporal differences will be related to water mass properties or other specific phenomena observed at the Lake surface from aircraft or ships and shore. A

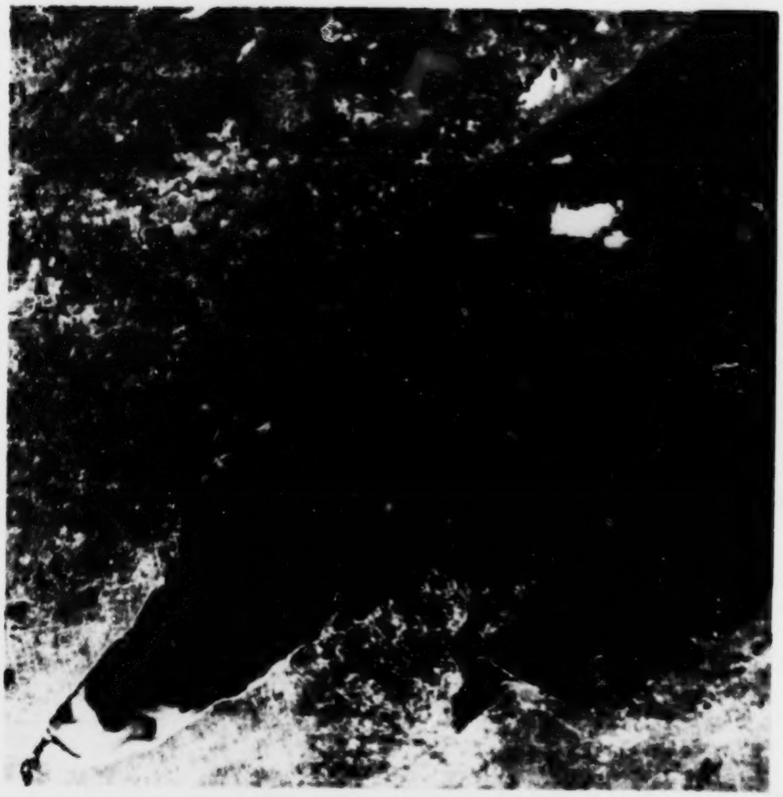


Figure 2: An ERTS-1 frame obtained on 12 August 1972 in the vicinity of Lake Superior. The measurements were obtained from the 0.6–0.7 micrometer channel of the MSS. Circulations in the western end of the Lake are revealed by sediment patterns.

third IFYGL task consists of satellite observations of hydrologic parameters in and around the Lake Ontario basin. This effort is exploring the utility of NOAA-2 and ERTS-1 observations for monitoring such hydrologic occurrences as cloudiness and precipitation, snow area, ice area, vegetation, and soil moisture patterns. A special effort is to be made to obtain visible, near-infrared, and thermal infrared data from satellites that will be useful in studies of Lake dynamics (Figure 3).

In conclusion, relatively little environmental monitoring of the Great Lakes has been done from space to date, and this has been of marginal utility. Satellites placed in Earth orbit recently, however, carry sensor systems that

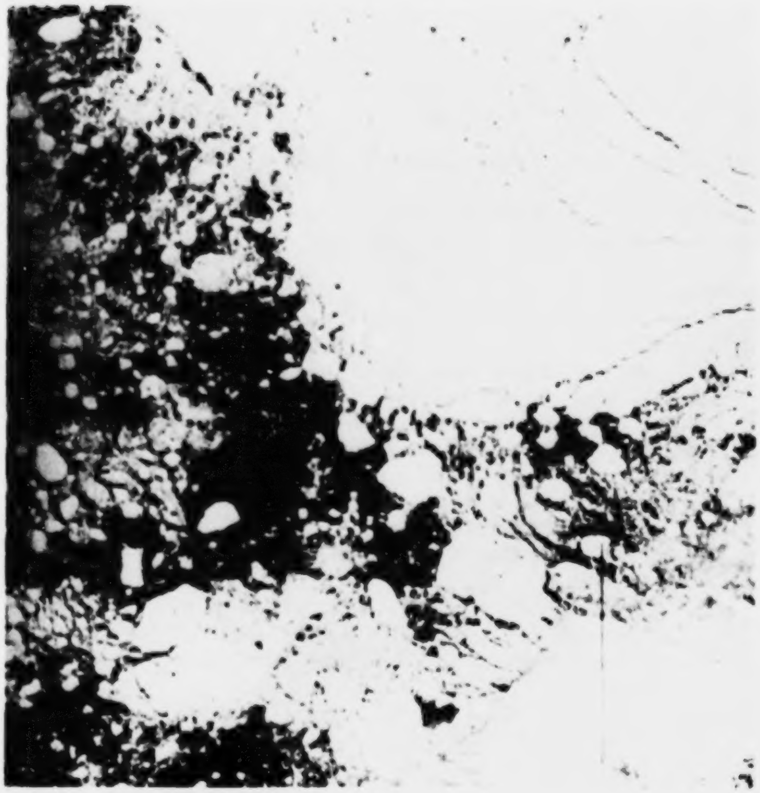


Figure 3: A variety of ice types and concentrations ranging from open to very close pack are illustrated in this single ERTS-1 frame 0.6–0.7 micrometer channel. The data were taken in the East Siberian Sea on 19 September 1972.

are better suited for this purpose than previous ones. This is expected to lead to more extensive and more useful data collection. Furthermore, the microwave portion of the spectrum, which is far less cloud and weather limited than the visible and infrared, is being actively explored for remote sensing applications. Both active (radar) and passive (radiometer) systems have been tested on aircraft, and the first scanning microwave radiometer carried on a USA satellite will be aboard the Nimbus E satellite launched this month. Active and passive microwave will be carried on the first manned SKYLAB next spring or summer, as well as an assortment of multispectral cameras and spectrometers of very high ground resolution. Thus there is much in the way of exciting new data from space to be expected in the months and years just ahead.

Precise Laser Navigation System (PLANS)

Louis Ervin, Maritime Administration
Department of Commerce

ABSTRACT

A. Authority
  (1) Rivers and Harbors Act 1970
  (2) Congress–funding
  (3) Corps of Engineers–responsible agency
  (4) 3-year Demonstration Program
B. Participation
  (1) Several federal agencies
  (2) Working committees
  (3) MARAD–Ice Navigation Working Committee
C. Background
  (1) Limited winter navigation season on Great Lakes
  (2) Inadequate floating navigational aids during winter season
  (3) No precise ship positioning system for use in narrow channels or rivers
D. Objective
  (1) Demonstrate practicability of season extension
  (2) Provide a ship-board navigation system for winter operations
  (3) Give shipmasters visual display of precise position (bow and stern) and speed in channel.
E. Tasks
  (1) Explore existing laser docking system as concept
  (2) Award contract fiscal year 1972–to study feasibility of precise laser navigation system
  (3) Successful tests of precise laser concept
  (4) Award contract fiscal year 1973–design, develop and test hybrid (radar) laser precise navigation system
  (5) Operational test precise laser navigation system on board ship, St. Marys River and St. Lawrence River
F. Operation
  (1) Controlled hybrid radar/laser beam directed to reflective targets ashore and returned to ship-board receivers. Radar used, with laser–gives all weather capability
  (2) Passive radar/laser retro-reflectors at turns, on channels, and rivers
  (3) Beam signal returned to receiver, then to computer, and finally to visual display in wheel-house

- (4) System will provide shipmaster with:
  - (a) All-weather positioning capability
  - (b) Real time visual display—automatically
  - (c) Ship's range, attitude (bow-stern relationship)
  - (d) Speed
- (5) Laser will meet all safety standards

G. Future
- (1) Assist with extension of winter navigation season
- (2) Provide safer transit of channels and rivers
- (3) Increase traffic and commodity movements
- (4) Reevaluation of insurance rates

* * *

One of the first identifiable problems of which we were made aware by operators on the Great Lakes was the lack of a navigational system for use in the channels confined because of ice, when floating aids to navigation are removed prior to winter free-up to prevent damage to these lighted buoys.

Section 107 (b) of P.L. 91-611 authorized a $6.5 million, 3-year program to demonstrate the practicability of extending the navigation season on the Great Lakes and St. Lawrence Seaway.

The Maritime Administration is a named agency in this program and has concentrated its efforts in the Ice Navigation Work Group of the Navigation Season Demonstration Program on the Great Lakes. After making several trips aboard Lakes boats during the winter season and talking with operators and shipmasters who had long experience in winter operations, it became obvious a resolution of this problem was of extreme urgency.

There is no system at the present time adequate to the needs of the Great Lakes operators. In an effort to remedy this problem, a laser docking system was purchased and installed on the steamer, *Phillip R. Clarke*, of U.S. Steel. Retro-reflectors were erected ashore on ranges and lighthouses in various locations in the St. Marys River. Tests of this equipment were successful and proved beyond doubt the applicability of a laser system for Great Lakes use. The primitive system we tested gave only two components: speed and distance from the shore reflector, which fixes the boat's position.

A contract was awarded in October 1972 to build a precise laser navigation system (PLANS) that will provide, in addition to speed and range, the attitude of the boat.

Certain of the deepened channels in the St. Marys River are 300 feet wide, with sharp bends occurring at Johnson Point and the Lime Island Turn. The Middle Neebish Channels that are used for upbound and downbound traffic during the winter are generally 27 feet deep. Thus a deeply loaded boat downbound has only 300 feet to maneuver in and actual practice dictates loading to the lighter depths. Partially offsetting this lighter loading is the approximately 3-feet higher water level currently being experienced in the Great Lakes.

With the newest Lakes boats being up to 1,000 feet long and 105 feet in width, it becomes readily apparent that a system will be required to indicate the attitude or lateral position of the boat in relation to the channel.

Lasers do not work efficiently in dense fog. The Great Lakes area is subject, during various times of the year, to fog conditions that would render a pure laser system inoperable for several weeks a year. To overcome this deficiency, PLANS will couple with the laser an inexpensive radar unit which will guarantee all-weather use. Combined passive laser radar retro-reflectors will be placed ashore. The shipboard installation will send and receive signals to and from these reflectors. The signal will be sent to a signal processor from which it is sent to a computer and finally directed to a visual display in the wheelhouse or other remote locations as necessary.

Specifications for this system are a 5-mile range, range accuracy to 3 feet, speed to 1/10 mile per hour, and altitude to less than 3 minutes of arc. This will all be visually displayed automatically in real time in the vessel's wheelhouse convenient for the Master and the wheelsman. The safety factor of the laser unit will meet the safety standards established by the U.S. government.

At this time it has not yet been determined whether a series of punch cards, switches, tapes, or other method will be used for the input of data into the system. This is an area that will be determined as the one-year contract is developed.

Assuming the use of plastic punch cards, the first trip up confined channels, such as the St. Marys River, would require manual operation of the system to input the data into the system. Ideally, this would occur during a period of clear visibility and good weather. Following the initial manual operation, PLANS will automatically determine the components named above. Sufficient capability will be built in for all the confined rivers and channels in the Great Lakes.

Additionally, information such as a tape record of speeds could be maintained to prove compliance with existing speed regulations. Remote units indicating speed alone could be placed in the engine room, for example, with the Master requesting and obtaining the required speed from the engineer on watch.

The unit is to be completed by October 1973, at which time a full scale demonstration test will be conducted on the St. Marys River with a minimum of 20 retro-reflectors. Hopefully, there will be sufficient retro-reflectors available for transiting the entire St. Marys River from DeTour to the Soo.

The many advantages of such a system are obvious, including night-time navigation on the St. Marys River, possibility for fewer strandings with consequent lower pollution hazards, and safer transits. The expected lower loss experience could result in insurance costs which would help offset the initial cost of PLANS

Man-Made Weather Patterns in the Great Lakes Basin

Helmut K. Weickmann, National Oceanic and Atmospheric Administration, Department of Commerce

ABSTRACT

For the past five years NOAA has studied the weather modification potential of the Great Lakes Region. Numerous observations of artificial rain and snowfall have been made in the Buffalo region of Lake Erie. Climatologically, the Great Lakes region is peculiar in that its numerous relationships between the water surfaces and the air exert particularly strong influences in the atmospheric boundary layer. In winter the entire Great Lakes Basin has a high frequency of shallow cloud layers which, upon traveling across the still unfrozen and warm lakes, form the basic ingredient for the development of Lake storms. The Basin is the seat of many industries whose pollution potential not only affects the hydrology and ecology but also the weather. The shallow cloud layers occur with sufficient depth to present a favorable precipitation potential but they are frequently not cold enough to produce ice crystals naturally. Consequently, these cloud systems constitute a source of artificial precipitation which is so far unexploited. Seeding applications are being discussed.

MAN-MADE WEATHER PATTERNS IN THE GREAT LAKES BASIN

In the heartland of the North American Continent is the Great Lakes Basin. It is not only a most interesting region for its hydrology, its population density, and its industrial growth, but also it is fascinating for its weather systems as it produces much of its own climate (Changnon, 1968).

The Great Lakes Basin encloses an area of more than 750,000 km^2 and has a water surface of 250,000 km^2. Thirty-two million people live within the Lake boundaries; twenty-eight million of them take their water requirements directly from the hydrological system of the Great Lakes Basin. This makes a daily total water consumption for industrial and private use of 15,600 million gallons. It is interesting to note that the average amount of snow falling from a typical Lake Erie "lake-storm" is 250,000 million gallons, or a 16-day supply of water for the population. During the period 4 November 1966 through 25 January 1969, 23 storms occurred (Jiusto and Kaplan, 1972); this was a water supply for one year. As the hydrology of all the Lakes is delicately balanced, it is obvious that the artifical manipulation of atmospheric resources over the Lakes may have a very significant influence on various human activities.

Climatologically, the Great Lakes region is peculiar in that its numerous relationships between the water surfaces and the air exert particularly strong influences in the atmospheric boundary layer. In winter the entire Great Lakes Basin has a high frequency of shallow cloud layers which, upon travelling across the still unfrozen and warm lakes, form the basic ingredient for the development of Lake-effect storms (Lavoie, 1972).

Figure 1 shows the mean cloudiness of North America in January. The Great Lakes Basin stands out with high cloudiness like an island. The reason for this high cloudiness is the annual course of evapotranspiration which shows over land a minimum in December and January and a maximum in June and August, while the Great Lakes often have negative evaporation during May and June, and have maximum evaporation in late fall and early winter due to storage of solar energy as sensible heat content during the summer months, with extreme values during days with lake storm events. The low level water source leads to the frequent occurrence of shallow supercooled cloud layers within the boundary layer. These cloud layers are generally 1700-1800 meters thick and often have cloud top temperatures warmer than -15°C. Few natural freezing nuclei are active at these warm temperatures and consequently there is a poor natural release of precipitation. Precipitation from these clouds can be released through artificial seeding. Their precipitation potential can be estimated from the rate of condensation in convective cloud layers based upon updraft speeds measured with a doppler radar. Table 1 gives hourly values of induced precipitation for various conditions of cloud thickness and temperature, assuming a 50% effectiveness of the seeding effort.

For the past 5 years the National Oceanic and Atmospheric Administration has studied the weather modification potential of the Great Lakes region. Numerous observations of artificial rain and snowfall have been made in the Buffalo region of Lake Erie. Several cases are listed in Table 2.

Intentionally-produced, man-made snowshowers of 25 November 1968 are shown in Figure 2. See Table 2 for cloud data. Note the optical density of the showers. Radar echoes of similar showers on 29 November are shown in Figure 3. On this day the clouds snowed out completely letting the sunshine come through. On 25 November other man-made snowshowers were discovered; these were, however, inadvertently caused by industrial pollution. The Basin is the seat of many industries whose pollution potential not only affects the hydrology and ecology but also the weather. For instance, large concentrations of highly effective freezing nuclei have been found downwind of the Bethlehem Steel Plant in Lackawanna near Buffalo. These nuclei have released downwind snowshowers on several occasions (Fig. 4). Of course, the famous La Porte, Indiana, anomaly may be another case of a possible pollution effect.

Figure 4 shows the flight path after the seeding experiment; the numbers written along the flight path are freezing nuclei concentrations measured with a carefully calibrated airborne acoustic ice nuclei counter. Note that downwind of Buffalo, Toronto, and the industrial center of Oshawa snowshowers formed, visible as radar echoes which were clearly related to the high concentration of artificial ice nuclei. The showers which developed on 6

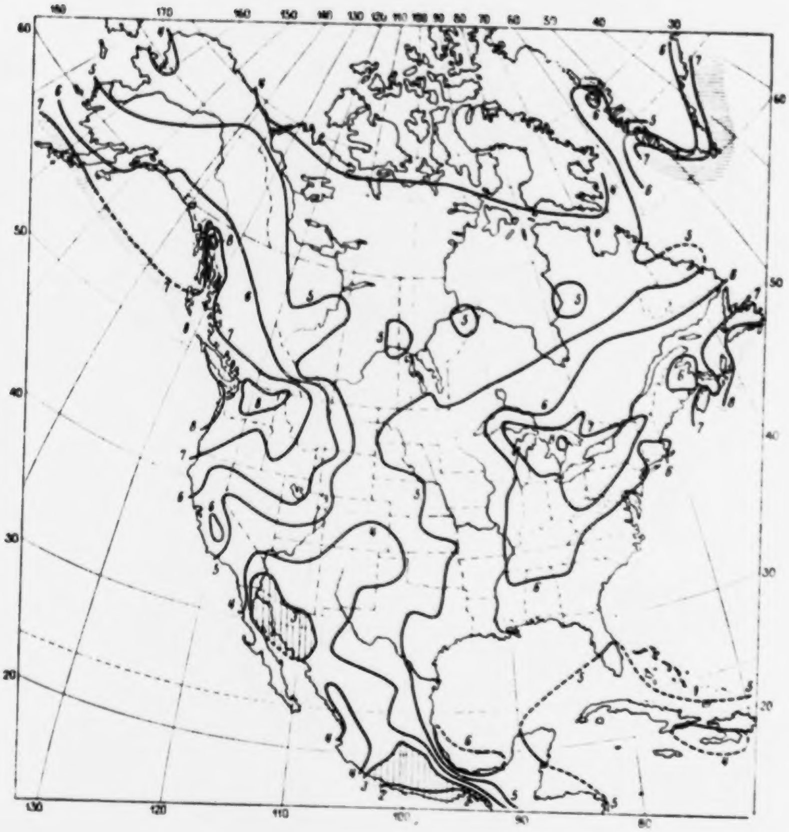


Figure 1: Average January daytime cloudiness over North America in tenths (after R. De C. Ward, et al., 1936).

Table 1: Estimate of induced precipitation—50% efficiency
Geographic area—Great Lakes

Stratus cloud thickness (in meters)	Temperature range (° C)	Updraft velocity (cm/sec)	Induced precipitation (mm/hr)
3000	0 to -22	10	1.73
3000	0 to -22	50	8.05
2000	0 to -15	50	4.50

Table 2: Initiation of precipitation

	Convective Layer				Stratiform Layer				Seeding	
	Base		Top		Base		Top			
Date	m	°C	m	°C	m	°C	m	°C	Type	Result*
13 Nov 68	900	-7	2000	-9					650 lbs dry ice racetrack	$\overset{*}{\bigtriangledown}$ 35 min. A.S.
25 Nov 68	900	-2	1800	-9.5	2100	-10	2400	-10.8	250 lbs dry ice circle	$\overset{*}{\bigtriangledown}^1$ 26 min. A.S.
29 Nov 68	700	-2	1800	-10.8					450 lbs dry ice 3 legs	$\overset{*}{\bigtriangledown}^1$ 1/3"/hr
2 Dec 68	300	+1	2400	-11					550 lbs dry ice	$\overset{\bullet}{\bigtriangledown}$ over lake
3 Dec 68	1000	+1.5	2600	-8	2700	-11.3	2900	-12.3	2400g AgI fuses	$\overset{\bullet}{\bigtriangledown}$ over lake
6 Dec 68	300	-6.5	1500	-12.0	1800		2100	-14.5	2400g AgI fuses 700 lbs dry ice	$\overset{\bullet}{\bigtriangledown}^{1-2}$ over lake $\overset{\bullet}{\bigtriangledown}^{1-2}$ 36 min A.S.

**Legend: $\overset{*}{\bigtriangledown}$ snowshower; $\overset{\bullet}{\bigtriangledown}$ rainshower; A.S. after seeding; and exponent ^{1} or ^{2} indicates intensity: ^{1} moderate and ^{2} heavy.*

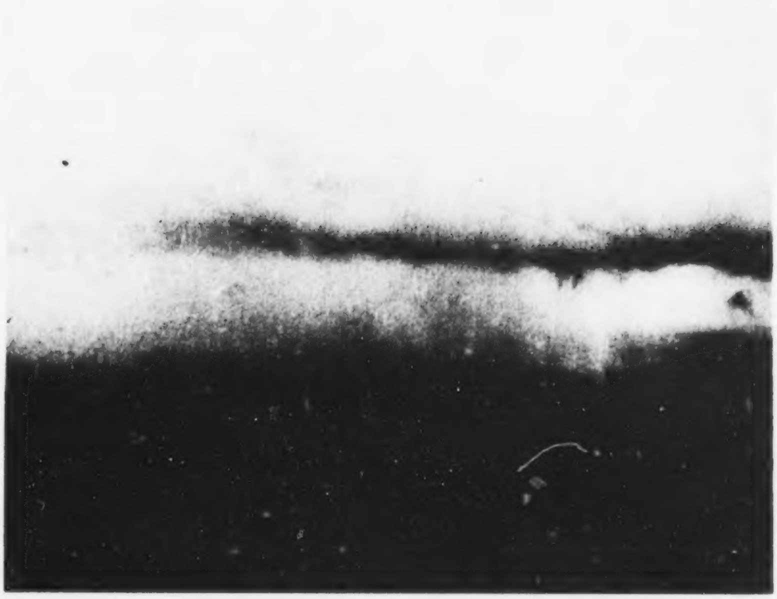


Figure 2: Artificial snowshower over the southern shore of Lake Erie on 25 November 1968.

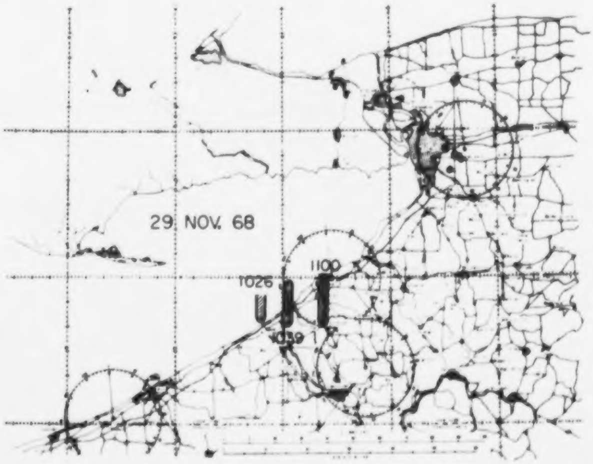

29 NOV. 68
1100
1026
1039

Figure 3: Radar echoes of snowshowers on 29 November 1968.

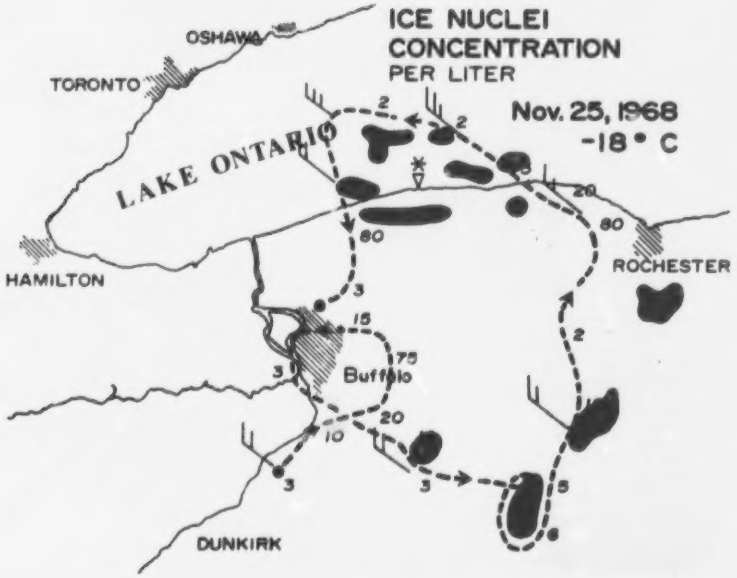


Figure 4: Radar echoes of snowshower produced inadvertently by anthropogenic nuclei downwind of industrial centers, 25 November 1968. The figure gives the flight path of the NOAA DC-6 and ice nuclei concentrations measured along the flight path.

December following seeding were much more intense; on the National Weather Service 10 cm WSR-57 radar they withstood an attenuation of 36 db, and during penetration with the aircraft we encountered gustiness and heavy precipitation as in a miniature squall line. The development of the echo areas following dry ice and AgI seeding is shown on Figures 5 and 6. The spreading of the seeding effect throughout the cloud deck by careful planimeterization of the radar echo areas is shown in Figure 7. It illustrates the superiority of the dry ice seeding from the cloud tops over the AgI seeding at cloud base: dry ice forms a curtain of ice crystals throughout the cloud layer, while AgI seeding produces only a line of crystals. The latter method takes about 20 minutes before the areal growth of its seeding parallels the dry ice growth. It must be mentioned, though, that after 20 minutes, the dry ice area contained about 60 crystals/1, while the AgI area contained about 20/1. The larger number of nuclei from dry ice seeding may have contributed to accelerating the spreading of the seeded area.

A similar squall line after seeding has been observed to form during earlier experiments over Lake Michigan (Weickmann, 1957).

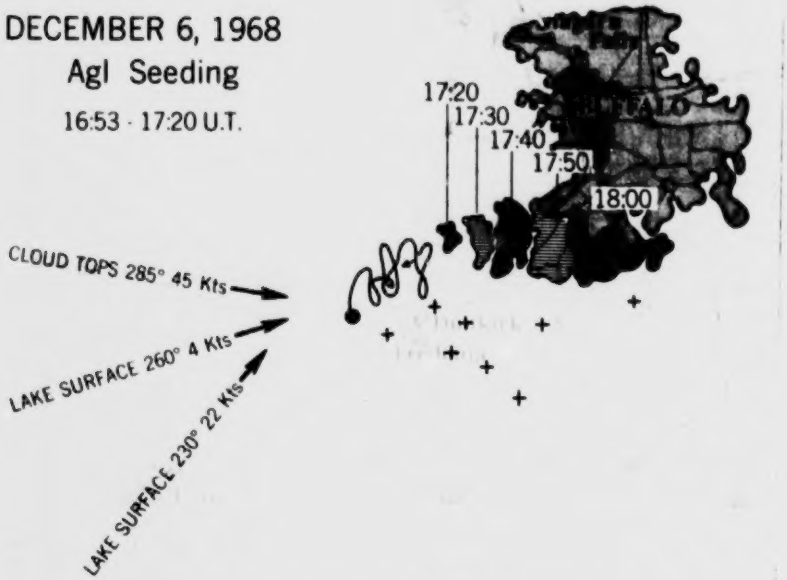

DECEMBER 6, 1968
AgI Seeding
16:53 - 17:20 U.T.
17:20
17:30
17:40
17:50
18:00
BUFFALO
Dunkirk
Fredonia
CLOUD TOPS 285° 45 Kts
LAKE SURFACE 260° 4 Kts
LAKE SURFACE 230° 22 Kts

Figure 5: The effect of AgI seeding on 6 December 1968. Note flight path during seeding and development of radar echoes following seeding.

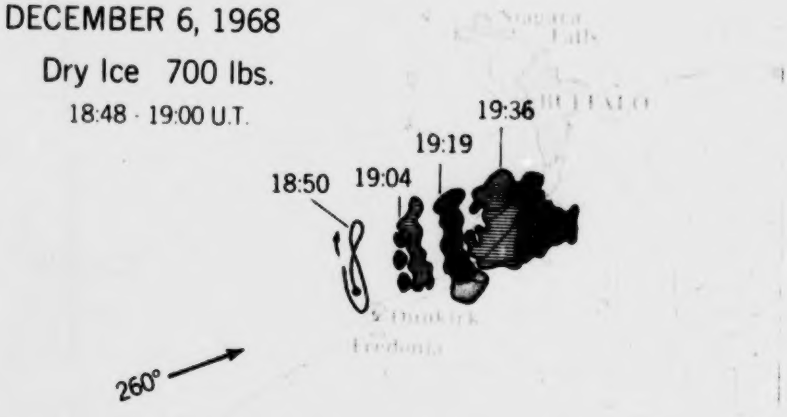

DECEMBER 6, 1968
Dry Ice 700 lbs.
18:48 - 19:00 U.T.
Niagara Falls
BUFFALO
19:36
19:19
18:50
19:04
Dunkirk
Fredonia
260°

Figure 6: The effect of dry ice seeding on 6 December 1968. Note flight path during seeding and development of radar echoes following seeding.

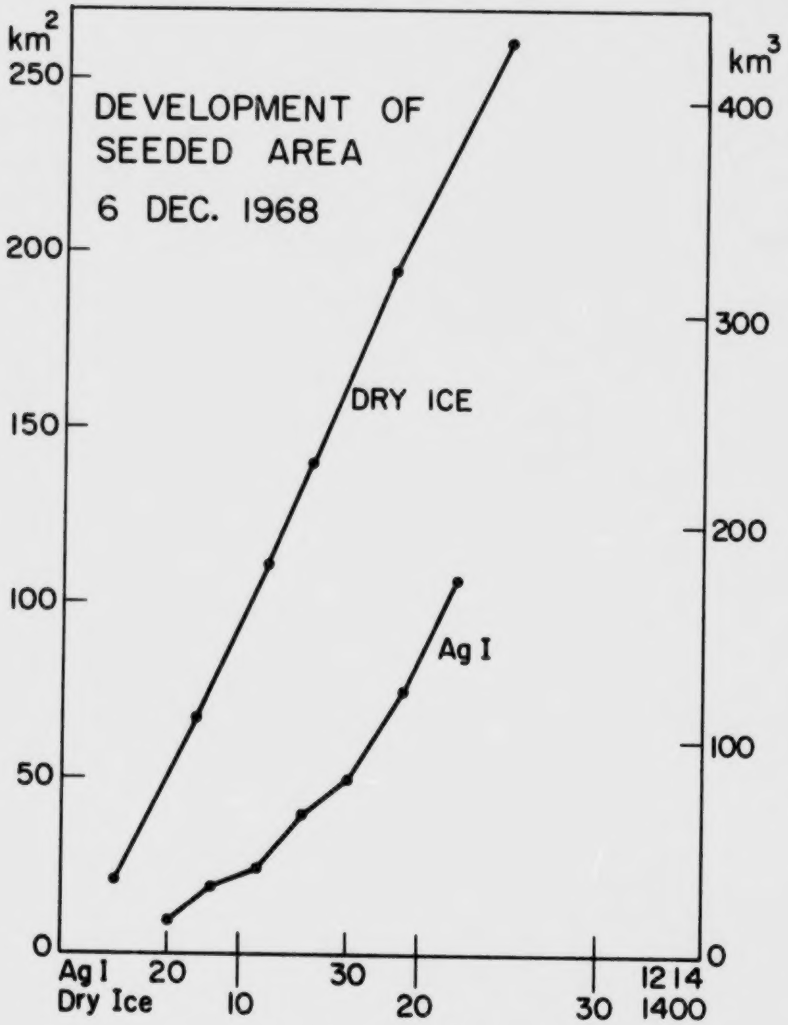


Figure 7: Areal spreading of AgI and dry ice seeding.

An efficient vertical transport mechanism exists for seeding material which is released at the surface. The formation of snowshowers in anthropogenic nuclei plumes as in Figure 4 testifies to this mechanism. We have explored this mechanism in an experiment on 4 December 1969 where a surface generator was placed at Millers Point, Canada, on the north shore of Lake Erie. AgI was

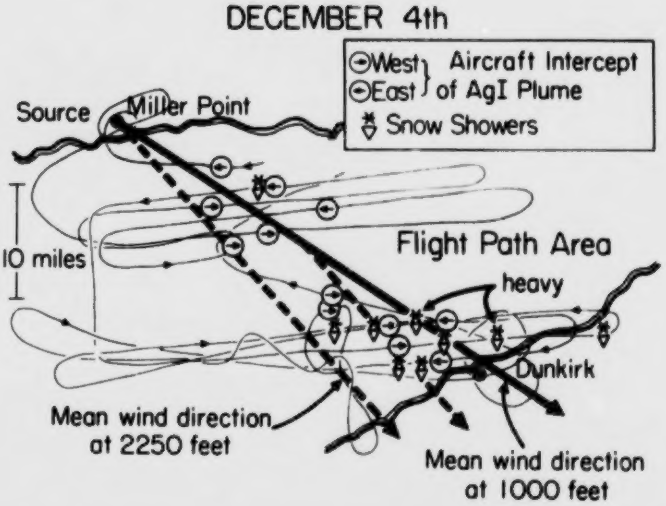

DECEMBER 4th
West
East
Aircraft Intercept of AgI Plume
Snow Showers
Source
Miller Point
10 miles
Flight Path Area
heavy
Dunkirk
Mean wind direction at 2250 feet
Mean wind direction at 1000 feet

Figure 8: Analysis of seeding effect when seeding was carried out with ground based AgI generator from Millers Point (Canada) on northern shore of Lake Erie, 4 December 1969.

released at a rate of 20 g/min from 1200-1330 EST. The plume was tracked across the Lake with an airborne ice nuclei counter mounted in the NOAA DC-6 aircraft, and Figure 8 indicates the result. The plume boundaries are marked and so are snowshowers that have begun to form near the southern shoreline. They appeared clearly on the Dunkirk radar operated by the Cornell Aeronautical Laboratory and their precipitation particles have been observed over land by ground teams of the State University of New York. Snowfall augmentation amounted to about 0.5-inch per hour. No clouds existed over the northern shore while clouds formed as the air moved across the warm lake.

The understanding of the mechanism of intensive Lake storms has been considerably enhanced by the Lavoie numerical model (Lavoie, 1972). Lavoie describes the applicability of his model for a study of precipitation processes which has been applied for a specific case by Magaziner (1972). He assumed and airflow along the axis of Lake Erie, wind speed 15 m/sec, and a Lake-air temperature difference of 12°C while the upstream inversion height was at 2000 m. He incorporated the formation of precipitation particles due to diffusion, due to riming, and due to crystal aggregation. Figure 9 illustrates the water equivalent of precipitation in the natural unseeded case. This pattern agrees well with observations made during similar storms, for instance, during the storm of 15-16 November 1969. When seeding was simulated using dry ice or AgI cartridges released at cloud top and generating 100 crystals/1

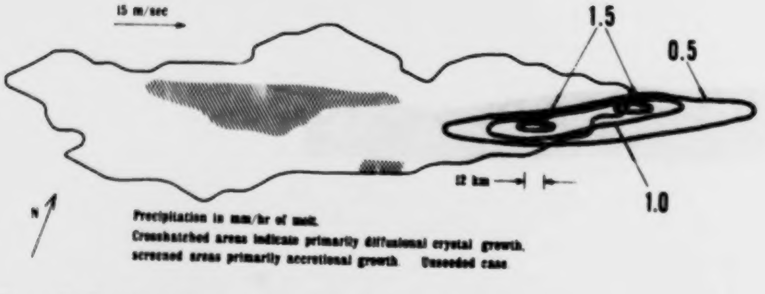

15 m/sec
1.5
0.5
1.0
12 km
N
Precipitation in mm/hr of melt.
Crosshatched areas indicate primarily diffusional crystal growth,
screened areas primarily accretional growth. Unseeded case

Figure 9: Result of numerical experiment of Lake-Effect Storm. Development of natural precipitation (Magaziner, 1972).

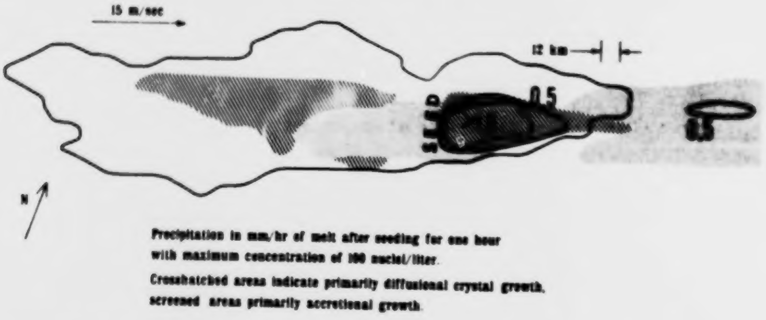

15 m/sec
12 km
SEED
0.5
0.5
N
Precipitation in mm/hr of melt after seeding for one hour
with maximum concentration of 100 nuclei/liter.
Crosshatched areas indicate primarily diffusional crystal growth,
screened areas primarily accretional growth.

Figure 10: Result of numerical experiment of Lake-Effect Storm. Development of precipitation after seeding (Magaziner, 1972).

along the line marked "seed" (Fig. 10), the distribution of precipitation changed drastically and most of it was discharged into the Lake before reaching the shore and metropolitan area of Buffalo.

The result of this numerical field experiment seen against the background of verification of the Lavoie model as reported by Lavoie (1972) may be a very real solution. It may, of course, not be the only solution that nature finds. But, if we were able to verify this solution on a naturally occurring storm, we would very well be on our way to manipulating artificially the lake level and contributing significantly to the water needs of millions of people. It is known that the lake levels undergo considerable annual variations reaching several feet in both directions for a mean level. Fortunately, the response time of the lake levels to precipitation and evaporation—the two main contributors—has a delay of about one year. Therefore, sufficient lead time is available for the effective experimental planning of water recycling into the Lakes.

CLOUD DISSIPATION

Another interesting weather modification potential over the Great Lakes Basin exists through the dissipation of extended supercooled cloud layers. This will not only contribute to the amelioration of frequently dreary winter climate, but it will directly affect the albedo of the weather system and through the albedo the energy source, namely the sun radiation, which ultimately drives the weather mechanism. Figure 11 shows a man-made weather scene over Thunderbay, Lake Michigan, after dissipation of about 175 km^2 of an extended supercooled cloud deck of the following characteristics: base 1350 m, -7.5°C, top 2100 m, -9.0°C. Seeding was done with 12 lbs of dry ice per mile along three parallel legs with three miles separation between each leg. Man-made blue sky is visible on top of the photograph which had been taken after descending through the opening in the cloud deck. Man-made snowshowers from a fourth seeding run are still visible in the background, while in the center of the picture cumulus clouds are forming due to initiation of convection and downward transport of moisture from the snowed out cloud deck. Numerous additional cases of cloud dissipation have been described elsewhere.

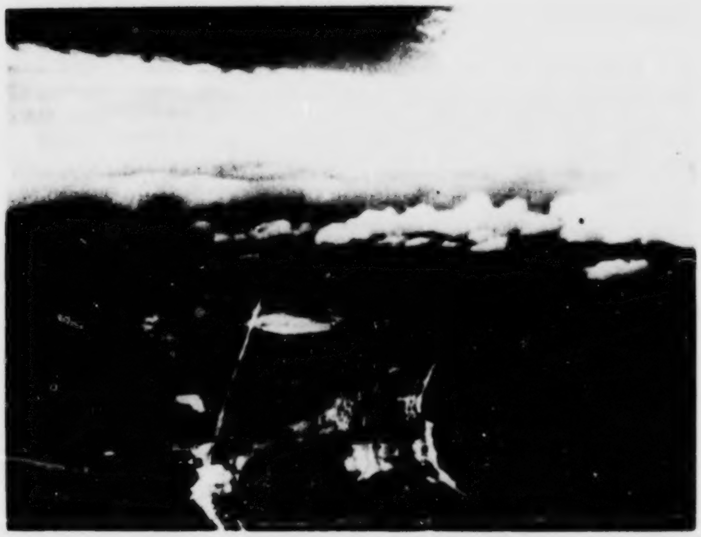
OUTLOOK

The potential of cloud modification during winter in the Great Lakes Basin has been sketched above. There is no doubt that the research accomplished so far is most promising for the application of seeding methods in a beneficial way for the population. How can "beneficial" be defined? Along the southern shore of Lake Erie and elsewhere, skiing areas exist. For these areas snowfall is beneficial while it may not be so for the communities in their environment for which snow is often a nuisance. During years of low lake level recycling of water back into the lakes would be beneficial for the water needs of the Great Lakes Basin population, industries, and water power requirements. The water needs of the city of Chicago constitute a special case. The tightly controlled lake hydrology causes problems with the water supply of the city of Chicago which has a water allotment from Lake Michigan of 1700 cubic feet/sec (cfs) while it needs are 3200 cfs.

Through systematic cloud seeding activities substantial amounts of precipitation could be added to Lake Michigan during wintertime which could easily accumulate to a 10-day supply at a present cost to the consumer of $3 million. During years of high lake level, atmospheric water can be exported to other neighboring water sheds, artificial snowfall can be targeted over skiing areas or cloud dissipating can be accomplished for the improvement of the climate.

It is conceivable that the Great Lakes Basin offers also during summer interesting possibilities for weather modification.

The many different configurations in the geographic boundaries between water and land cause natural convergences in the low level, the so-called Ekman flow. These areas are predestined for the development of clouds and the organization of showers. We believe that La Porte, Indiana, is located in



80 MIN AFTER SEEDING

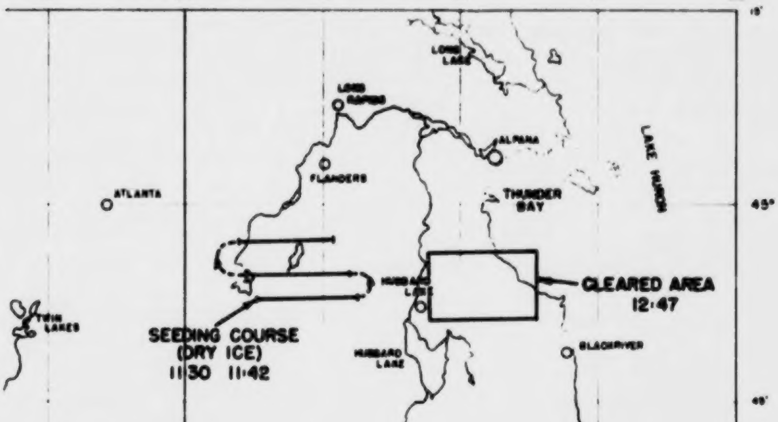

15'
84°
45'
30'
15'
83°
15'
45°
45'
30'
LONG LAKE
LONG RAPIDS
ALPENA
FLANDERS
ATLANTA
THUNDER BAY
LAKE HURON
HUBBARD LAKE
TWIN LAKES
SEEDING COURSE
(DRY ICE)
11:30 11:42
CLEARED AREA
12:47
HUBBARD LAKE
BLACKRIVER
AU SABLE R
GLENNIE
0
10
20
STATUTE MILES
WIS STATE

Figure 11: A man-made weather scene over Thunderbay, Lake Michigan.

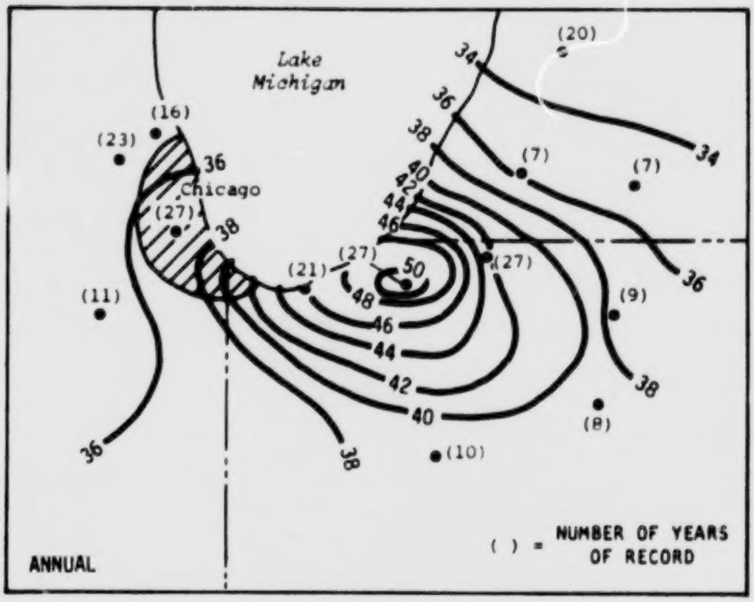


Figure 12: Average annual pattern of number of thunder days at Chicago-La Porte area based on 1942-68 period (Huff and Changnon, 1972).

such an area. For the prevailing westerly flow, the land area around the southeast Lake corner will be an area of natural convergence of air coming across the water and air coming over land along the southern shore region. This will cause *a priori* a high year-round shower activity, and it is entirely plausible that the ice nuclei sources in the Gary, Indiana, industrial complex contribute to enhance the precipitation efficiency in that area. Figure 12 shows the area of increased precipitation in that region (Huff and Changnon, 1972). Most likely more such areas of natural convergence exist in the Basin.

The exploration of all these possibilities of weather modification is planned by NOAA in a program designed and executed jointly with universities and private research institutions in that region. A thorough assessment of not only the meteorological and climatological problems, but also of the legal, international, socio-economic, and ecological implications is planned before major seeding experiments can be designed.

The first phase of this comprehensive study would be directed primarily to Lake Michigan and should involve contracts with local universities and research institutions. It should produce:

1. A climatology of cloud populations, their characteristics and their area extent, including a study of the natural convergence mechanisms within the boundary layer.

2. A study of the hydrological response connected with weather modification in the Great Lakes Basin.
3. An evaluation of the legal and international implications of precipitation modification considering both advantages and disadvantages and including criteria for legal proof of precipitation augmentation.
4. A study of the short term and long range socio-economic impacts of weather modification activities on the immediate area as well as through the Great Lakes Basin.
5. Further development of a numerical precipitation prediction model on the scale of the Great Lakes Basin capable of incorporating seeding effects in a parametric form.

STUDIES PRESENTLY PROPOSED

1. Mesoscale Wintercloud Census of the Lake Michigan Basin
   W. A. Lyons, University of Wisconsin/Milwaukee
2. Synoptic Climatology of Favorable Event Occurrences
   E. W. Wahl, University of Wisconsin/Madison
3. Climatology of Precipitable Water and Downwind Longwave Radiation
   K. Bayer, University of Wisconsin/Milwaukee
4. Climatonomy of the Lake Michigan Region
   H. Lettau, University of Wisconsin/Madison
5. Legal Analysis of the Feasibility of Precipitation Augmentation over the Great Lakes
   D. D. Smith, University of Wisconsin/Madison
6. Confirmation of Seeding Effects on Clouds and Precipitated Water
   V. Suomi, University of Wisconsin/Madison
7. Field Studies of Seeding Agent Dispersion and Inadvertant Weather Modification
   W. A. Lyons, University of Wisconsin/Milwaukee
8. Studies on Numerical Modeling and Modification of Precipitation over the Great Lakes Basin
   F. Baer, University of Michigan
9. Hydrologic-Economic Feasibility Study on Precipitation Augmentation over the Great Lakes
   W. Ackermann and G. Stout, Illinois State Water Survey
10. Precipitation Constituents Received in an Area Downwind of Urban Pollution Sources.
    G. E. Merva, E. H. Kidder, Michigan State University
    and N. D. Strommen, NOAA, NWS Climatologist for Michigan.
11. Pilot Seeding Program on Lake Michigan
    H. Weickmann, B. Phillips, NOAA-Atmospheric Physics and Chemistry Laboratory

It is planned that the initial experimental phase will be dealing with an investigation of areal and downwind effects of seeding, i.e., with studies of the impact of seeding on the target and downwind areas. It should be emphasized that the purpose of this project is solely to assess its research aspects and basic feasibility. Final operational applicability will not be within the jurisdiction of the research institutions.

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Research Grants for Fisheries of the Great Lakes

Dr. Stanford Smith, National Marine Fisheries Services,
National Oceanic and Atmospheric Administration,
Department of Commerce

Fishery responsibilities and activities on the Great Lakes are administered by the Regional Director of the Northeast Region of the National Marine Fisheries Service (NMFS) at Gloucester, Massachusetts. Exceptions are biological research and the contract with the Great Lakes Fishery Commission for sea lamprey control and research, which was transferred to the Bureau of Sport Fisheries and Wildlife at the time that the National Oceanic and Atmospheric Administration (NOAA) was created in 1970. NMFS was formed under NOAA from the former marine fishery functions of the Bureau of Commercial Fisheries and the Bureau of Sport Fisheries and Wildlife (BSFW). This union has incorporated nearly all federal fishery authorities in a single agency, giving NMFS broader capability and responsibility than any former fishery agency.

Many of the Great Lakes fishery programs that were active prior to 1970 were reduced or discontinued due primarily to budget stringencies when NMFS was created. Research grants to states have continued and funding has increased modestly, however. The projects supported by grants are making a substantial contribution to information needed to evaluate and guide fishery restoration programs and for management of the fishery resources of the Great Lakes.

The grant-in-aid for fisheries program of the National Marine Fisheries Service is an on-going state-federal partnership concerned with research, development, and enhancement of the nation's fishery resources. In the Great Lakes states grants for fisheries work are authorized under two Acts.

The Commercial Fisheries Research and Development Act of 1964

This legislation (P.L. 88-309 as amended) authorizes the Secretary of Commerce to cooperate with the 50 states, Puerto Rico, and the governments of the Virgin Islands, Guam, and American Samoa to carry out research and development activities to improve the nation's commercial fisheries. Cost-sharing projects are funded at either a 50 percent or 75 percent level for the federal contribution depending upon the expected distribution of benefits anticipated to accrue from a project. Certain resource disaster projects are fundable to 100 percent federal contribution. This Act was recently amended by P.L. 92-950 which extends the termination date to June 30, 1978.

Authorization of funds for the research and development projects remains at the $5-million-dollars-per-year level, but the disaster section of P.L. 92-950 increases the authorization from $650,000 to $1.5 million per year.

During fiscal years 1966 through 1972, 43 projects for commercial fishery research and development in the Great Lakes states have been approved for a total cost of $2,152,000 (federal share $1,617,000). The major emphasis has been upon biology of lake trout, lake herring, catfish, white bass, and yellow perch to obtain information necessary for evaluation of fishery rehabilitation programs and for management. Two projects have assisted different states in modernizing and equipping a research vessel and a research laboratory. It is notable that the first use of the disaster provisions of P.L. 88-309 occurred in 1965 when the commercial fishery of the Great Lakes was assisted with $400,000 to alleviate a market failure resulting from an occurrence of botulism in processed chubs.

The role of the National Marine Fisheries Service in providing assistance to the Great Lakes states through grant-in-aid projects constitutes a small but significant portion of the larger overall effort of the states and other public agencies.

Studies of the introduction of hatchery reared lake trout stocks into Lake Michigan have continued since 1965. These studies by the states bordering the Lake have provided general information on restoration of the species and have been most helpful for management decisions of individual states and the Lake Michigan Management and Research Committee of the Great Lakes Fishery Commission.

Assessment of fish populations is one of the primary objectives outlined in "A Prospectus for Investigation of the Great Lakes Fishery," Document 64-10, Great Lakes Fishery Commission. In keeping with this charge, projects of Michigan and Wisconsin include the planned attainment of stock appraisal which provides information on several aspects of the Commission's fishery rehabilitation program and objectives. These are: (1) progress and effectiveness of sea lamprey control of different geographic areas of Lake Michigan; (2) survival of planted trout as affected by exploitation of the commercial and sport fisheries and by predation; (3) dispersal and distribution of year classes of planted trout; (4) utilization of food supplies, growth, maturation and spawning success in various geographic areas; (5) associations and interactions with other species; (6) effects of chlorinated hydrocarbons and heavy metals on the reproductive potential, survival and growth of lake trout; (7) effects of internal and external parasites on lake trout; (8) economic statistics of the commercial and sport fisheries.

The projects supported by NMFS under the Commerical Fisheries Research and Development Act have constituted a substantial portion of the state contributions to the overall fishery rehabilitation endeavor. All jurisdictional agencies on the Great Lakes have cooperated in these programs, which are coordinated by the Great Lakes Fishery Commission through its Management and Research Committees.

Wisconsin and Minnesota also participate in a somewhat similar assessment program in Lake Superior with each state coordinating its efforts to provide information on lake trout and associated species to guide fishery restoration and management plans. Here again, the projects supported by NMFS funds provide substantial assistance to each of these states so that they can contribute effectively to the larger assessment program of national and international scope that constitutes the efforts of all U.S. and Canadian agencies concerned with Lake Superior, under coordination by the Great Lakes Fishery Commission.

In addition to participating in the lake trout assessment program, Wisconsin has a project to study the lake whitefish in Lakes Superior and Michigan. Historically, lake whitefish have experienced extreme fluctuations in abundance for reasons not completely understood. It is hoped that by determining the factors both enhancing year class strength and leading to strong adult populations a more knowledgeable management plan for the whitefish fishery can be instituted. This project will cover a three-year period ending June 30, 1975.

Lake Erie has also benefited from commercial fishery research and development funds. Ohio has just terminated a two-year study to determine the commercial importance of white bass and channel catfish in the Lake and in Sandusky Bay. The relative abundance of each species in these waters and the effectiveness of various commercial gears has been studied so that accurate predictions of harvestable crops can be determined.

Pennsylvania has recently concluded a three-year project entitled "A Study to Establish a Program to Increase the Production of High Value Commercial Fishes in Lake Erie." Initially it was hoped that restoration of the once valuable blue pike fishery could be achieved. The study sought to evaluate the feasibility of success in a program to augment blue pike populations.

Early efforts to obtain blue pike for artificial rearing were undertaken utilizing the expertise of commercial fishermen in 1967 with chartered vessels. Gill netting was done over traditional blue pike grounds in May but was not successful. During 1968, four adult fish thought to be blue pike were captured and held for observation at the Linesville, Pennsylvania, hatchery. Two fish survived to be used in propagation experiments in the spring of 1969. One female became sufficiently gravid for spawning; the other, a male, was used for egg fertilization. Although species identification was vague, it was thought that the male was a true blue pike, that the female was an intergrade between walleye and blue pike. Reluctantly, everyone concluded that some blue pike progeny would be obtained from the back cross. About 9,000 swim-up fry survived to be transported to the Gavin's Point National Hatchery in South Dakota. To ensure survival, plans were made to release advanced young in a remote pond as free from other fish as possible. Through the courtesy of Minnesota's Department of Conservation, 525 three-inch fingerlings were released in Little Horn Lake.

Attempts were made in August and October 1970 to recover the fingerlings. Extensive netting produced no yearling blue pike, but sizable quantities of yellow perch, 500 about 5- to 9-inches long, which probably were terminal predators on the "blue pike" fingerlings.

Of 100 fingerlings held at the Gavin's Point Hatchery, none survived to enable positive identification. Pennsylvania biologists have examined many ostensible blue pike after 1968 but have not found any that met all criteria for blue pike identity. They are convinced that pure Lake Erie blue pike are no longer to be caught.

The Pennsylvania Fish Commission hopes to initiate a new five-year project in the eastern basin of Lake Erie. It will have two major objectives: (1) to assess the structure and status of smelt and other forage fish populations, and (2) to study the stability and development of yellow perch year classes.

Commercial fishery research and development funds have been used for many other activities in the Great Lakes states. A few years ago the Bureau of Sport Fisheries and Wildlife granted a long term lease of its Cape Vincent Hatchery to the New York Conservation Department. One of the first projects approved in New York provided for the refurbishing of the buildings to provide adequate laboratory facilities and housing for the laboratory director.

Pennsylvania's research vessel *Perca* was lengthened and equipped with required fishing gear and navigation instruments as part of its Lake Erie project. A few more modifications are planned in the new project which was mentioned previously.

Anadromous Fish Act of 1965

The second grant-in-aid program administered by the National Marine Fisheries Service in the Great Lakes states is the Anadromous Fish Act (P.L. 89-304, as amended). It authorizes the Secretary of Commerce to enter into cooperative agreements with states and other non-federal interests for the conservation, development and enhancement of the anadromous fishery resources of the nation and the fish in the Great Lakes that ascend streams to spawn. The program is administered at the federal level jointly by the NMFS and Bureau of Sport Fisheries and Wildlife. Federal funds up to 50 percent may be used to finance project costs. However, the federal share may be increased to 60 percent when two or more states having a common interest in any basin jointly enter into a cooperative agreement with the Secretary. This Act, as amended by Public Law 91-249, will expire on June 30, 1974.

During fiscal years 1967 through 1972, the NMFS participated in 16 anadromous projects for Great Lakes fisheries with a total cost of $970,000. The varied activities supported included research on fish diseases and parasites; biology of alewife, smelt, sturgeon, and walleye; studies of fish spawning reefs in Lake Erie; and an on-going evaluation of food processing techniques for Great Lakes salmon.

At the present time there are a few anadromous fish projects underway in the Great Lakes area. Michigan is completing the final year of a three-year project to study parasites and diseases of anadromous sport and commercial fish species. The project has two primary objectives. One is to develop efficient diagnostic and treatment techniques for controlling common diseases and find methods for rapid identification and control of diseases for which transmission and therapy are presently unknown. The second objective of this work, which is being carried on at the Grayling Fish Disease Laboratory, is to reduce unnecessary waste of the fish resources due to heavy infestations of parasites which may cause such species to be discarded by sport fishermen or barred from commerical sales.

An important result of the project will be the issuance of a field manual of fish diseases. This will provide descriptive material of all diseases, color plates, and will be prepared in loose-leaf form to enable updating with additional material.

A second project in which NMFS is participating is being conducted by the Wisconsin Department of Natural Resources through a subcontract with the Food Science Group at the University of Wisconsin in Madison. The introduction of the coho salmon into the Great Lakes system has created a most valuable sport fishery, and it also presents a potentially valuable commerical fishery. Little research had been carried out on the applicability and feasibility of using traditional processing methods for Great Lakes coho intended for human consumption. Several years ago an attempt was made to assess the commercial value of Lake Michigan coho. These were canned and compared to ocean-caught coho with the result being very unfavorable for the fresh water grown fish.

However, the Lake Michigan coho used in the early canning experiments were mature fish taken during their spawning run. It is believed that prime condition, lake-caught coho will probably yield high quality food products. The results of the first year's research have shown that tremendous food quality changes occur during sexual maturation of both coho and chinook salmon from Lake Michigan. In addition, pronounced flavor defects were noted in mature salmon from certain parts while other locations yielded fish with less pronounced defects. Samplings have indicated that the flavor of deep-lake caught salmon is comparable to salt water reared coho. However, the texture and color is more like commercially processed ocean pink salmon than ocean coho salmon. Continued research will be devoted to developing processing methods which will improve and optimize the desirable characteristics of Great Lakes salmon.

The work being carried on in the Great Lakes area under the NMFS grant-in-aid programs reflects the continuing interest of the National Oceanic and Atmospheric Administration in the rehabilitation and optimum use of Great Lakes fishery resources. The states have used the maximum allotments available to them under the Commercial Fisheries Research and Development Act, and anadromous fish projects are supported to the greatest extent possible within the limits of available funds. A recently published report entitled "Grant-in-Aid for Fisheries, 1972" may be obtained by writing to the Regional Director, NMFS, Gloucester, Massachusetts 01930. This report covers all projects funded nationally through the grant-in-aid programs.

NASA Great Lakes Regional Earth Observations Program

Herman Mark and Richard Gedney, Lewis Research Center,
National Aeronautics and Space Administration

ABSTRACT

For more than a decade NASA has been working toward earth applications of space technology—looking in towards the earth. Perhaps the best known of the accomplishments have been the communications satellites which are in commercial use today for telephone and television transmission. Others include the polar orbit weather satellites presently operated by NOAA and the synchronous orbit technology satellites still being developed by NASA which have been providing time-lapse pictures of the entire planet on a daily basis. Some years back the agency took steps to enlarge the application of this satellite technology to additional problems for which these developments could aid in providing solutions. Once this decision was made the subsequent marriage between satellite technology and the environmental problems plaguing the country was so natural that the programs in earth environment monitoring almost designed themselves and the effort was in full swing. Recognizing the expertise available in many of the previously earth-bound agencies, NASA joined with a number of them (USDA, USDI) at several organizational levels. This cooperative pattern has been followed since that time to provide new orbital vision for agency duties that could best be handled in this way.

At the NASA Lewis Research Center in Cleveland a number of projects seemed appropriate for this developing technology. These projects, where were discussed at the ICMSE Conference on Great Lakes Research, are listed below.

Remote Sensing of Great Lakes Ice Coverage

The program objectives are the application of various remote sensing techniques (radar, photographs, thermal images) for monitoring ice type and ice coverage on the Great Lakes. The primary usage of the data collected will be to aid in extension of the Great Lakes-St. Lawrence Seaway navigation season. Automation data processes will be developed to permit eventual all-weather collection and transmission from satellite information to aid navigation during extended shipping seasons on the Lakes.

Remote Sensing of Great Lakes Water Quality for Entire Water Bodies

The program objectives are to develop techniques for remote sensing of water quality of entire water bodies in the Great Lakes region. Observation of spectral response (visible and IR) of the Lakes will be correlated with water sample measurements made by Canada Centre for Inland Waters (CCIW) and other agencies.

Application of Satellite Data Collection Systems for Water Quality Monitoring and Limnology

The objective of this activity is to demonstrate and thereby stimulate interest in the use of satellite relay systems for data collection from transponders located on the surface of the earth. This work is done in direct cooperation with "user" agencies. Through these joint efforts we endeavor (1) to establish the usefulness of such satellite systems, (2) to determine system limitations, and (3) to assess the effectiveness of such systems for the purpose of improving existing methods of data collection. Currently two areas are being investigated. One deals with collection of water quality data; the other deals with the circulation of water in a large lake due to wind-driven currents.

Numerical Modeling of Lake Currents

A numerical model which predicts the time-depending wind-driven currents in Lake Erie is being developed. Because the spacial distribution of water quality parameters is greatly dependent upon lake currents, this numerical model will be used as an aid in designing methods for remotely sensing total lake body water quality.

* * *

HISTORY OF AGENCY ROLE

For more than a decade, NASA has been working toward the development of earth applications of space technology. The overall objectives of such an effort include defining those real world problems to which already developed space technology could make a really beneficial contribution. Experience has shown that this application requires an organized effort at technology transfer, system development, and demonstration before it can be expected that the technology will be used appropriately and optimally or even at all. An example of the sequence of efforts required is that given in Figure 1 for the Earth Resources Survey Program. It is clear that efforts are required not only of a technical nature (the first five listed), but a very critical final step involving preparing users is also necessary before the developed system goes into general use. Recognizing this, the Interagency Coordination Committee for Earth Resources Program was formed (Figure 2) with representation from seven other federal agencies along with NASA. This committee performs the high-level coordination required and reviews the overall program along with providing executive guidance on substantive issues. This eases considerably the coordination at the working level among members of these agencies and this information meeting is an example of the latter effort.

The history of other NASA applications programs development is shown in Figure 3 (Meteorology) and Figure 4 (Geodesy). These programs were developed by NASA over the last decade, slowly bringing them into operational use by the appropriate agency. In the case of meteorology NOAA (formerly ESSA) is, of course, heavily involved. Figure 5 gives the chronological development of the Earth Resources Survey Satellite program, culminating in the ERTS-A launch in July 1972, now the successful ERTS-I. ERTS-B and Skylab EREP (Earth Resources Experiment Package) are also shown scheduled for launch in 1973. In the latter case, that of Earth Resources, there have arisen many discipline areas, each of which has its own requirements for information and its own students and eventual uses and systems. Several of these are shown as examples in Figure 6 (Oceanography), Figure 7 (Forestry, Agriculture, Geography) and Figure 8 (Hydrology and Geology). The figures list accomplishments that have already been made in these discipline areas by remote sensing from aircraft. The common question that is asked on each is: Can this be done from satellite? The main reason for this last question really is "can this capability be taken to satellite altitude *and be made cost effective*?" This question is never overlooked.

In a general examination of the possibilities and potential of remote sensing we find that many useful and interesting studies are yet required. Some of these are shown in Figure 9. To accomplish these very desirable goals for bringing satellite observation capabilities to optimum use for our earthbound needs, an extensive program is ongoing, conducted and managed by NASA. Several examples of sensor and instrument systems development being carried out at the Goddard Space Flight Center and others are shown in Figure 10. A few examples of studies aimed at improving techniques for meteorological applications are shown in Figure 11. Measurement techniques as well as atmospheric circulation models are being developed and improved. Effects of the atmosphere on information transferred is also being vigorously investigated.

Much of the problem of developing systems that can be useful for management decisions lies in the area of data and information handling, processing and display. The amount of data that can be obtained remotely is overwhelming and a great deal of the development effort therefore must be directed towards solving the problem of processing such data into the form required by the decision maker. NASA research and technology plans for a number of such studies are shown in Figure 12. Goddard Space Flight Center, Marshall Space Flight Center and the Manned Spacecraft Center of NASA are among the groups working on such problems and managing similar efforts at very high competence group centers.

It has been found useful and necessary to break the overall applications program into a number of discipline categories in order to use the large store of existing capability that has been built up in the past. It has been the NASA plan to involve these established disciplines in the development of modern and innovative techniques that would advance the discipline area but which operational groups or even researchers in a given area would not have considered without stimulation. It is a difficult and sensitive role but many of the agencies represented here today have already seen the advantage of applying space agency-generated technology to their own problems. These include NOAA's use of weather satellites, and the U.S.G.S. of the Department of the Interior using the ERTS imagery they described today and which they presently dispense at nominal cost from their EROS Scientific Data Center in Sioux Falls, S.D. Some of the work along disciplinary lines that is ongoing in Agriculture, Forestry, Geology, Hydrology, Land Use, Ecology, Oceanography, Geodesy and Geophysics is shown in Figures 13 and 14.

In this sensitive role as stimulator, NASA has recognized the transfer of funds as a very effective device for generating interest and the history of the examples of the USDA, USDI, and USDC are given in Figures 15, 16 and 17. Important to note here is the very effective stimulation of internal funding in these various agencies of the NASA transfer funds. The real stimulus of course, in each case, has been the value of the program itself. By 1971 the agencies shown were all funding, on their own, the satellite programs originally induced by NASA. Clearly fund transfers are becoming less and less necessary as agencies, seeing the advantages of the programs to the carrying out of their responsibilities, are independently and increasingly funding their own satellite derived programs.

The overall 1972 NASA Office of Applications budget is shown in Figure 18 and it can readily be seen that there is quite a good mix of aircraft, satellite and supporting research and technology programs. This year's budget (FY 1973) is at roughly the same level and the program is again aimed at generating useful applications and developing systems appropriate to these applications with cost/benefit ratio and system technological superiority as the major considerations involved.

Locally Oriented Earth Observations Program

One important part of the overall agency Earth Observations Program is the Locally Oriented Applications Program. This sub-program attempts to capitalize on the geographical distribution of the scientific and technological capability of the ten in-house centers plus the contractor at JPL. Thus the Lewis Research Center located in Cleveland, Ohio, has the responsibility of developing those applications which pertain especially to the Great Lakes/Midwest Region of the country. The portions of this locally oriented program that refer to the Great Lakes in particular and hence are appropriate to this ICMSE conference will be described in greater detail at this point. These efforts presently to be described do not constitute the total local area program. We shall include only those programs in which NASA Lewis Research Center is working directly on Great Lakes problems which can be eased or modified by application of remote sensing from aircraft or satellites. The first of these is the program to develop remote sensing for snow and ice mapping. This program (Figure 19) has as its goal the development of an all-weather system for the provision of accurate ice-type distribution maps as aids to navigation for ships traveling on the Great Lakes during the ice season.

The Winter Navigation organization, created by Congress in P.L. 91-611 was formed for the purpose of providing a 3-year demonstration of the feasibility of extension of the Great Lakes shipping season. The shipping season is presently only 8 months long and the efforts of the board, the working committee, as well as of all associated groups, are being directed towards evolving a series of studies and, where possible, demonstrations. Together these will show where the problems are that limit the season and will also rank the problems according to difficulty, whether from the technological, environmental or economic point of view. The program of the Winter Navigation organization is aimed at dealing with the problems caused by the yearly extensive icing conditions that develop in the Great Lakes. In Lake Erie, an ice boom has been installed at the entrance to the Niagara River through the cooperative efforts of the U.S. and Canada which bounds ice packs that form near Buffalo, New York. Great Lakes shippers are always eager to cross the ice as early as possible and as late as possible during the shipping season, and transits, often made in this and other areas such as the Welland Canal, frequently rely on information on ice conditions gathered by such vessels as the Coast Guard Breaker *Ojibway*. It is clear from the extent of such activities at present that even more shipping would occur during the winter season if additional aids to navigation were made available. The NASA Lewis Research Center's Program is aimed at determining the best means of providing optimum routing and other ice information at operational frequencies and getting this information into the hands of shipping captains, to aid them in travelling on the Lakes during the period of ice cover.

At the present time we are obtaining true color visible and false color infrared imagery of Lake ice as well as thermal imagery from two thousand to ten thousand feet altitude. We are also obtaining radar imagery of the Lake from aircraft. The radar provides all weather imagery, while the visible images are used to help interpret radar data. Thermal imagery used to aid interpretation can also be used for obtaining surface temperature histories and thus to assist in predicting freeze-up.

To develop an automated ice classification technique would be most desirable. Ice appears in many forms and types, and it can have a highly variable history. In an attempt to process the data obtained by these various techniques, a number of computer programs have been written which count, characterize, and identify objects with an aim to provide automatic scanning and analyzing capability and thus to avoid human photo interpretation, which limits the rate at which image information can be obtained. The eventual goal of this wide-ranging effort is to provide an automatic information gathering system which can possibly be taken to satellite altitude and used to provide navigational aids as required.

EARTH RESOURCES SURVEY PROGRAM

NASA OBJECTIVES

DEFINE REAL WORLD PROBLEMS TO WHICH SPACE TECHNOLOGY CAN MAKE A BENEFICIAL CONTRIBUTION

DETERMINE PERFORMANCE OF REMOTE SENSORS, ESTABLISH SIGNATURE RECOGNITION CRITERIA

DEVELOP SENSORS, SUBSYSTEMS, AND EXPERIMENTAL SPACECRAFT, ALONG WITH EFFICIENT MEANS FOR GETTING INTO ORBIT

DETERMINE SCOPE AND CONFIGURATION OF OPERATIONAL SYSTEMS (INCLUDING SPACECRAFT, AIRCRAFT, AND GROUND SEGMENTS)

DEVELOP DATA HANDLING TECHNIQUES

ASSIST USER AGENCIES IN DEVELOPING A COMMUNITY OF EXPERTS PREPARED TO UTILIZE SPACE-DERIVED REMOTE-SENSING DATA

Figure 1: Earth Resources Survey Program.*

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*Figure 1 through 19 were presented as overhead projections at the conference.

INTERAGENCY COORDINATION COMMITTEE
FOR EARTH RESOURCES SURVEY PROGRAM

FUNCTION: REVIEWS TOTAL ERS PROGRAMS
AND SUBSTANTIVE ISSUES

CHAIRMAN
Dr. Homer Newell, NASA

DEPT OF AGRICULTURE
Dr. Theodore C. Byerly

DEPT OF DEFENSE
Dr. Manfred Eimer

DEPT OF STATE
Dr. Robt. F. Packard

OFFICE SCIENCE & TECH
Dr. Russell C. Drew

DEPT OF COMMERCE
Dr. John W. Johnson

DEPT OF INTERIOR
Dr. Vincent C. McKelvy

CORPS OF ENGINEERS
Dr. John W. Jarman

NASA
Mr. Charles Mathews

EXECUTIVE SEC'Y
Dr. David Williams, NASA

Figure 2: Interagency Coordination Committee for Earth Resources Survey Program.

METEOROLOGY

1962	FIRST CONFERENCE ON REMOTE SENSING ON THE ENVIRONMENT
1963	AUTOMATIC PICTURE TAKING TIROS VIII - (DAYTIME CLOUDS)
1964	HIGH RESOLUTION INFRARED IMAGERY NIMBUS I (NIGHT TIME CLOUDS)
1965	FIRST OPERATIONAL ADVANCED VIDICON CAMERA SYSTEM-- ESSA II
1966	FIRST SYNCHRONOUS ORBITAL SATELLITE ATS-I (CONTINUOUS CLOUDS)
1970	ESSA VIII, NIMBUS IV, ATS-III
1972	SYNCHRONOUS METEOROLOGICAL SATELLITE DCS FOR 10,000 PLATFORMS

Figure 3: History of Meteorology Program.

GEODESY

1962 GEODETIC SATELLITE PROGRAM ESTABLISHED

1964 BEACON B

1965 BEACON C

1. GEODETIC QUALITY DOPPLER TRANSMITTERS
2. LASER RANGING CORNER REFLECTORS

1965 GEOS I

1966 PAGEOS I

1968 GEOS II

VERY HIGH PRECISION ± 10 METERS

Figure 4: History of Geodesy Program.

EARTH RESOURCES

1965	EARTH RESOURCES PROGRAM BEGAN (WITH DATA FROM NIMBUS, ALSO GEMINI PHOTOS)
1966	AIRCRAFT PROGRAM (ER SURVEY) LOCATED IN SPACE APPLICATIONS OFFICE
1967	R D SOURCES FOR EROS SOUGHT (INTERIOR HAS SINCE WITHDRAWN)
1968	800K COST BENEFIT ANALYSIS BY NASA HQ
1969	NASA FORESEES NEED FOR ERTS 2 DESIGN STUDIES AT 500K EACH
1970	CONTRACTOR NAMES (G. E.) TO BUILD EARTH RESOURCES TECHNOLOGY SATELLITE 50×10^6 FOR SATELLITE, GROUND DATA HANDLING SYSTEM AND 6 DC PLATFORMS
1972	ERTS-A LAUNCH
1973	ERTS-B LAUNCH SKYLAB PROGRAM INCLUDES EREP

Figure 5: History of Earth Resources Program.

[illegible]

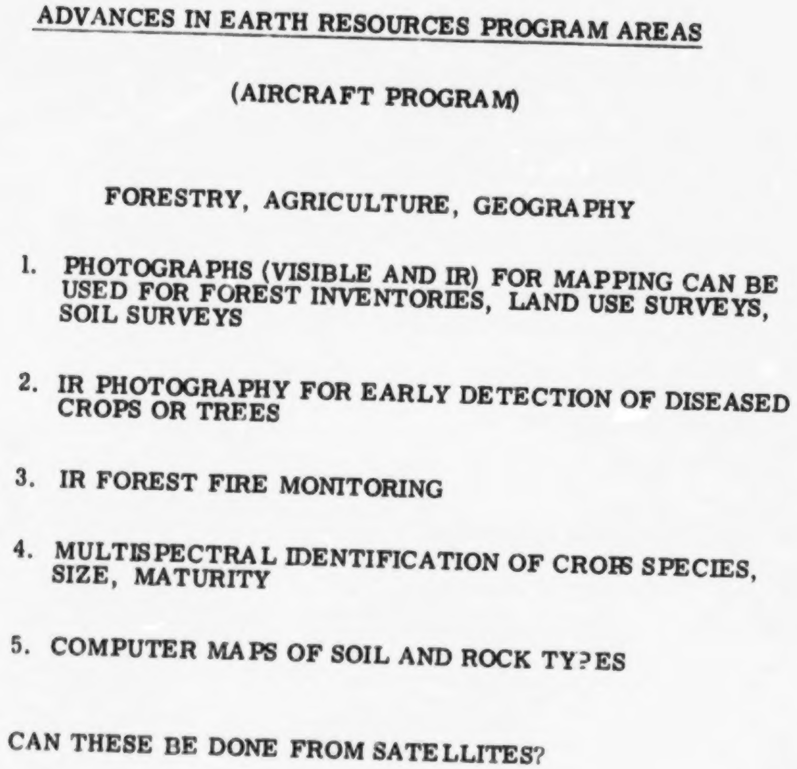
(AIRCRAFT PROGRAM)

OCEANOGRAPHY

1. **SEA SURFACE TEMPERATURE MEASUREMENTS VISIBLE, INFRARED, MICROWAVE**
2. **SEA SURFACE CURRENTS**
3. **SEA STATE**
4. **SEA ICE**
5. **MARINE LIFE DETECTION**

CAN THESE BE DONE FROM SATELLITES WITH THE REQUIRED QUALITY?

Figure 6: Advances in Earth Resources Program areas.



ADVANCES IN EARTH RESOURCES PROGRAM AREAS

(AIRCRAFT PROGRAM)

FORESTRY, AGRICULTURE, GEOGRAPHY

1. PHOTOGRAPHS (VISIBLE AND IR) FOR MAPPING CAN BE USED FOR FOREST INVENTORIES, LAND USE SURVEYS, SOIL SURVEYS
2. IR PHOTOGRAPHY FOR EARLY DETECTION OF DISEASED CROPS OR TREES
3. IR FOREST FIRE MONITORING
4. MULTISPECTRAL IDENTIFICATION OF CROPS SPECIES, SIZE, MATURITY
5. COMPUTER MAPS OF SOIL AND ROCK TYPES

CAN THESE BE DONE FROM SATELLITES?

Figure 7: Advances in Earth Resources Program areas.

ADVANCES IN EARTH RESOURCES PROGRAM AREAS

(AIRCRAFT PROGRAM)

HYDROLOGY AND GEOLOGY

1. IR IMAGERY FOR TRACING FRESH WATER DISCHARGE INTO SALT WATER
2. LOCATE HOT SPRINGS WITH IR
3. SNOW AND WATER SURVEYS AND SUBSURFACE WATER (SOIL MOISTURE)
4. GEOLOGY PROGRAM INITIATED TO ATTEMPT A GEOLOGIC SURVEY OF GROUND FEATURES. VERY DIFFICULT, MANY PARAMETERS (>100 TO BE IDENTIFIED FROM SPECTRIAL SIGNATURE)

CAN THESE BE DONE FROM SATELLITES?

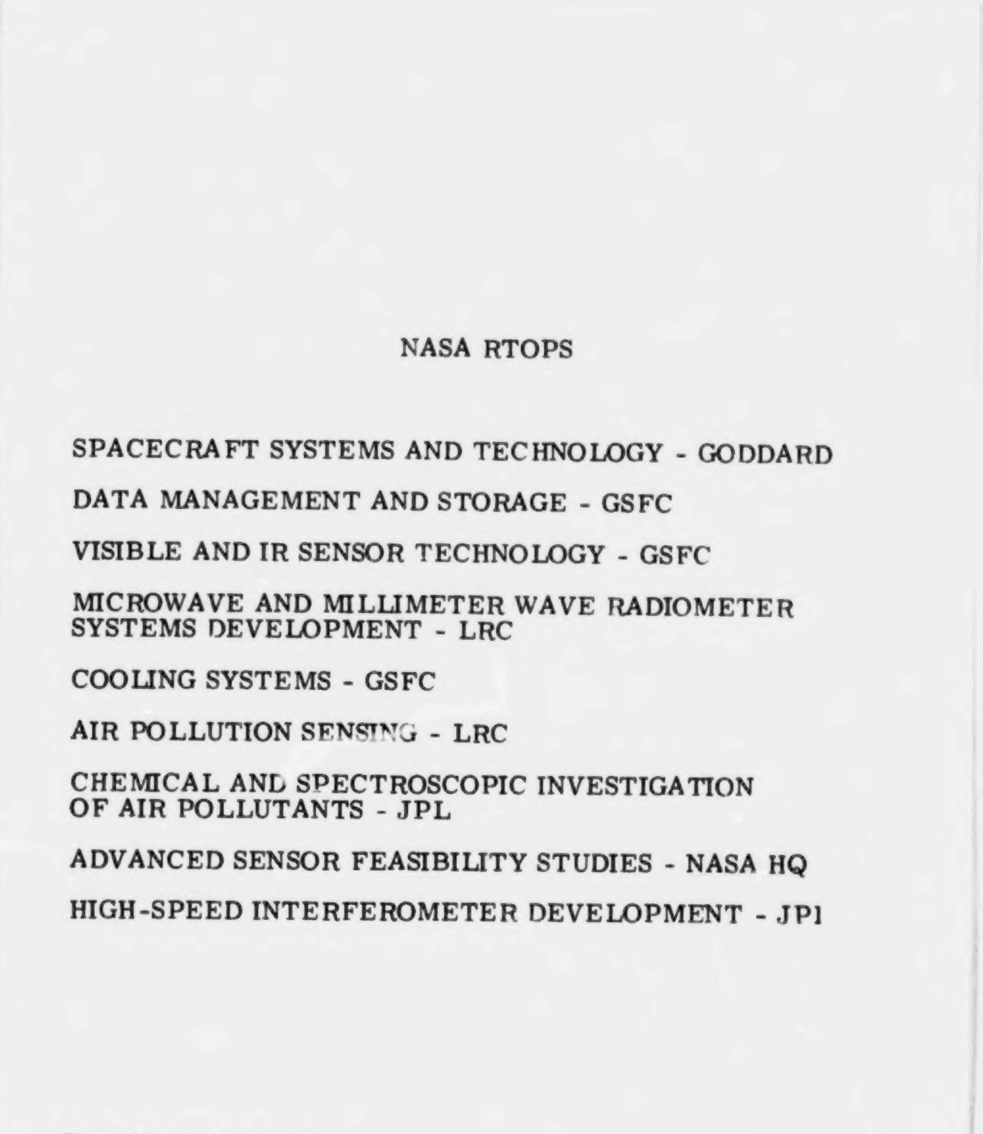
Figure 8: Advances in Earth Resources Program areas.

EARTH OBSERVATION NEEDS

(BY ANY MEANS)

1. 3-D FIELDS OF DENSITY, VELOCITY, TEMPERATURE AND WATER CONTENT (TO BE USED FOR WEATHER MODELS)
2. RATES OF CONTINENTAL DRIFT AND UPLIFT
3. MONITOR TOTAL WATER CONTENT OF POLAR ICE CAPS AND GLACIERS
4. SEA SURFACE STATE ON ALL SHIPPING LANES
5. MARINE BIOLOGICAL RESOURCES MONITORING
6. EXACT OCEAN HEIGHTS FOR STUDY OF OCEAN MOVEMENT
7. IMPROVED AUTOMATIC IDENTIFICATION FOR AGRICULTURE, FORESTRY AND GEOLOGY
8. ATMOSPHERIC INTERFERENCE EFFECTS,
9. IMPROVED INSTRUMENTATION DESIGN, PACKAGING AND RELIABILITY
10. DATA HANDLING AND DISTRIBUTION NETWORK

Figure 9: Earth Observation Needs.



NASA RTOPS

SPACECRAFT SYSTEMS AND TECHNOLOGY - GODDARD

DATA MANAGEMENT AND STORAGE - GSFC

VISIBLE AND IR SENSOR TECHNOLOGY - GSFC

MICROWAVE AND MILLIMETER WAVE RADIOMETER SYSTEMS DEVELOPMENT - LRC

COOLING SYSTEMS - GSFC

AIR POLLUTION SENSING - LRC

CHEMICAL AND SPECTROSCOPIC INVESTIGATION OF AIR POLLUTANTS - JPL

ADVANCED SENSOR FEASIBILITY STUDIES - NASA HQ

HIGH-SPEED INTERFEROMETER DEVELOPMENT - JPL

Figure 10: NASA RTOPS.

NASA RTOPS

DEVELOPMENT AND OPTIMIZATION OF REMOTE SENSING TECHNIQUES FOR METEOROLOGICAL APPLICATION - GSFC (LONG-TERM WEATHER FORECAST GARP)

APPLICATION OF METEOROLOGICAL SATELLITE DATA TO GENERAL CIRCULATION MODELS - GISS

CLIMATOLOGICAL MODELS OF THE ATMOSPHERE AND CLOUD COVER - MSFC

CALCULATING ATMOSPHERIC TRANSMITTANCE - JPL

ATMOSPHERIC EFFECTS ON REMOTE SENSING - ARC

USE OF APOLLO PHOTOGRAPHY FOR MESOSCALE METEOROLOGY - MSC

Figure 11: NASA RTOPS.

NASA RTOPS

EARTH RESOURCES SENSING INSTRUMENTATION - GSFC

CALIBRATION, EVALUATION AND SIMULATION OF ER MULTICHANNEL SURFACE SENSORS - GSFC

DATA MANAGEMENT INFORMATION, EXTRACTION OF PROCESSING - GSFC

PRESENTATION, MANIPULATION, VALIDATION AND RECORDING OF IMAGE DATA - GSFC

ER STUDIES WITH NIMBUS IMAGERY - GSFC

HARDWARE FOR HANDLING AIRCRAFT AND SPACECRAFT ACQUIRED DATA

INSTRUMENTS FOR SENSING ER FROM AIRCRAFT AND MANNED SPACECRAFT

UNIVERSITY OF MICHIGAN SPECIAL (UV, VIS, IR, MW) COMPETENCE GROUP - MSC

ER DATA ANALYSIS, INSTRUMENTATION AND TECHNIQUES-MSFC

Figure 12: NASA RTOPS.

NASA RTOPS

AGRICULTURE AND FORESTRY REMOTE SENSING RESEARCH AND TECHNOLOGY - HQ. A. PARK

SPACECRAFT OCEANOGRAPHY PROJECT - HQ. A. PARK

GEOLOGIC REMOTE SENSING PROGRAM - HQ. A. PARK (USGS - CONTINUOUS SINCE 1965)

HYDROLOGY - USDI - HQ. - M. DEUTSCH (50,000 DATA COLLECTION STATIONS)

GEOGRAPHY, URBAN, REGIONAL AND ENERGY BUDGET CHANGE DETECTION AND PREDICTION HQ. A. PARK (USGS - GEOGRAPHIC, LAND USE, ETC.)

NATURAL AND CULTURAL RESOURCE MANAGEMENT USDI - NASA HQ. - A. PARK

PURDUE APPLICATIONS ANALYSIS - MSC

PUBLIC HEALTH ECOLOGY - MSC

LASER RADAR MEASUREMENTS OF MARINE ATMOSPHERE LANGLEY RESEARCH CENTER

DEVELOPMENT OF CHESAPEAKE BAY ECOLOGICAL TEST SITE FOR REMOTE SENSING APPLICATIONS - NASA WALLOPS

DEVELOPMENT OF REMOTE SENSORS TO DETERMINE WATER QUALITY

REMOTE SENSING OF EARTH AND ATMOSPHERE FROM AIRCRAFT

Figure 13: NASA RTOPS.

NASA RTOPS

EARTH DYNAMICS - GSFC

EARTH OBSERVATIONS ADVANCED STUDIES - JPL

EARTH OBSERVATIONS PROGRAMS OFFICE SUPPORT - JPL

PHYSICAL OCEANOGRAPHY - NASA - WALLOPS VA

IMPROVED OCEAN GEODESY - WALLOPS

PRECISION SATELLITE TRACKING - WALLOPS, JPL, GSFC

VERY LONG BASELINE INTERFEROMETRY
WALLOPS, JPL, GSFC

OCEAN PLATFORM POSITIONING - WALLOPS
(100 METERS OR BETTER, 5 CM/SEC)

DATA MANAGEMENT - WALLOPS, JPL

LOW ALTITUDE SATELLITE MAGNETOMETRY - GSFC

INSTITUTIONAL SUPPORT - GISS

NATIONAL SPACE SCIENCE DATA CENTER - GSFC

Figure 14: NASA RTOPS.

USDA SUPPORTED REMOTE SENSING PROGRAM

65	66	67	68	69	70	71
50	232	349	484	664	835	1,330

NASA TRANSFER FUNDS

66	67	68	69	70
847	550	1,400	1,460	1,322

Figure 15: Remote Sensing Program funding history USDA.

USDC SUPPORTED SATELLITE OPERATIONS

1969	1970	1971
18,727	16,478	25,820

METEOROLOGICAL RESEARCH

	1969	1970	1971
USDC	2,442	2,510	2,951
NASA	2,270	2,106	2,106

Figure 16: USDC supported satellite operations.

USDI EARTH RESOURCES PROGRAM

	1969	1970	1971
USDI	.2	1.1	1.6
NASA FUNDS	1.8	1.8	1.9

Figure 17: USDI Earth Resources Program.

1972 NASA BUDGET

	FY 1970	FY 1971	FY 1972
SPACE APPLICATIONS	128,304	167,000	182,500
EARTH RESOURCES SURVEY	26,000	59,950	48,500
ERTS (A AND B)	(15,000)	(48,950)	(37,500)
AIRCRAFT PROGRAM	(11,000)	(11,000)	(11,000)
EARTH OBSERVATORY SAT STUDIES	-	-	1,000
SYNCHRONOUS MET SATELLITE	2,700	10,850	13,000
COOPERATIVE APPLICATIONS SATELLITE	83	100	2,600
GLOBAL ATMOSPHERIC RES PROGRAM	-	1,000	2,500
METEOROLOGICAL SOUNDINGS	3,000	3,100	2,500
TIROS/TOS IMPROVEMENT	3,700	3,200	1,600
APPLICATIONS TECH SATELLITE	38,965	30,300	60,300
RADIO INTERFERENCE AND PROP STUDY	438	1,000	1,000
GEODETIC SATELLITES	1,700	1,700	1,300
AIR TRAFFIC CONTROL SATELLITE STUDIES	-	3,000	-
SRT/ADVANCED STUDIES	24,479	27,500	25,100

Figure 18: 1972 NASA Budget for space application.

I - HL-1 - 160-75-13

REMOTE SENSING FOR SNOW AND ICE MAPPING

GOAL: - THE APPLICATION OF REMOTE SENSING TECHNIQUES TO THE PROVISION OF ACCURATE ICE-TYPE DISTRIBUTION MAPS AS NAVIGATION AIDS TO SHIP CAPTAINS ON THE GREAT LAKES DURING THE EXTENDED SHIPPING SEASON.

Figure 19: Local program for remote sensing for snow and ice mapping.

The Lewis Research Center's Earth Observation Program for Water Quality and Limnology

Richard T. Gedney and Herman Mark, Lewis Research Center, National Aeronautics and Space Administration

INTRODUCTION

The objective of the Earth Observation Program for Water Quality and Limnology at the Lewis Research Center is to develop applicable remote sensing methods for satellites or aircraft. The mode of operation for developing the methods is to work directly and jointly with the potential user to ensure that his specific needs will be satisfied by the methods. Once the methods are developed, it is intended that they are to be applied operationally by the user.

REMOTE SENSING OF ENTIRE WATER BODIES

The spectral characteristics of a water body can be related to many of the water body's parameters. Pollutants, biota, suspended sediments and turbid effluents all affect the transmission of light in the water as well as the reflected spectrum from the water. Satellite and aircraft acquired electromagnetic radiation data can provide a synoptic and rapid assessment of the spectral characteristics of large water bodies such as the Great Lakes. This remotely sensed data can then be used to determine the entire lake water quality and to give limnological information.

For example, remotely sensed chlorophyll concentrations in the surface water will indirectly give the water body's eutrophic state since the chlorophyll concentrations can be related to total aquatic productivity. In addition remotely sensed lake turbidity and temperature assists in determining such features as upwelling, dispersion of river effluents, long-shore transport phenomena, thermal effluent and lake circulation patterns. As an illustration of the synoptic potential of remote sensing for the Great Lakes we will now examine some recent Earth Resources Technology Satellite (ERTS) photographs for turbidity profiles.

ERTS Great Lakes Images

Figure 1 gives the reflectance vs. wavelength curve for water with high concentrations of particulate matter. The reflectance in the .50 to .70 micrometer wavelength band is significantly greater at the outfall where the particulate concentration is the highest than at 400 meters from the outfall where particulate concentration is less. The reflectance in the .5 to .7 micrometer band can be shown to be related to particulate concentration. The four-band multispectral scanner (MSS) on ERTS continuously scans the Earth's surface producing continuous strip imagery. The four-spectral bandwidths are .5 to .6, .6 to .7, .7 to .8 and .8 to 1.1 micrometers and are designated respectively MSS bands 4, 5, 6 and 7. The field of view shown by the images are 100 x 100 nautical miles with a nominal spatial resolution of 260 feet. Figure 2a gives the positive ERTS MSS band 7 image of part of the southeast shore of Lake Huron and the north shore of Lake Erie in the neighborhood of Long Point. Figure 3 should be used to determine the location of places referred to in this paper. In band 7 (.8–1.1 micrometers) the water is highly absorbent and appears dark. In the Long Point area no major river inflows of particulate matter occur. The areas of high suspended particulate concentration can be determined from Figure 2b which gives the band 5 image of the same area at the same time as Figure 2a. The areas of high particulate concentration appear as light areas in the image and in Lake Erie they occur along Long Point and partly west of Long Point. However, no high particulate concentration appears along the most western part of the Lake Erie shore.

The images shown in Figures 2a and 2b were taken on September 9, 1972, during which time there was a N10E wind at approximately 10 mph as recorded by the Cleveland and Erie U.S. weather stations. The wind history prior to this time was such as to make the quasisteady wind driven current analysis of reference 1 approximately valid. Presented in Figures 2c to 2e are the calculated currents for a N15E wind at 10.1 meters/sec. Although these conditions are not exactly the same as on September 9, they are close enough to draw qualitative comparisons with the ERTS images. The currents presented in Figures 2d-2e show strong upwelling in the neighborhood of Long Point where Figure 2b shows large suspended particulate concentrations. It is very possible (though not yet proven) that the source of high particulate concentration is from the Lake bottom and transported to the surface by upwelling currents.

Shown in Figure 4 are the ERTS MSS band 7 and 5 images taken on September 9 of the central and western basins of Lake Erie. The indication (see Figure 4b) of the high concentration of suspended particles along the south shore reflects in part the high volume of turbid river outflow along the shore. Particularly noticeable is the discharge of (1) the Black River into the Lorain breakwater, (2) the Sandusky Bay, (3) the Huron River and (4) the Grand River into Fairport Harbor. The high concentration of suspended particles in the western basin of Lake Erie is also readily discerned in Figure 4b.

Past and Present Remote Sensing Programs

One past Lewis Research Center water quality measurement program was that of the underwater camera and flash unit shown in Figure 5. In cooperation with the Environmental Protection Agency in Fairview Park, Ohio, the Lewis Research Center built this instrument to automatically photograph algae formations on a lake bottom. The camera was used during Project Hypo in 1970 and a complete description of the camera system and its application can be found in reference 2.

Over the past year, the Lewis Research Center has been involved in a joint project with the Canada Centre for Inland Waters to develop techniques for the remote sensing of water quality of entire water bodies in the Great Lakes region. Observations at aircraft altitude of spectral response (visible and IR) of the Lakes is being correlated with water sample measurements made by the Canada Centre for Inland Waters at the locations shown in Figures 6 and 7. Correlations between the spectrometer data and such parameters as chlorophyll concentration and suspended solids is evolving.

APPLICATION OF SATELLITE DATA COLLECTION SYSTEMS FOR WATER QUALITY MONITORING AND LIMNOLOGY

Objectives

The objective of this activity is to demonstrate and thereby stimulate interest in the use of satellites relay systems for data collection from transponders located on the surface of the Earth. This work is done in direct cooperation with "user" agencies. Through these joint efforts we endeavor (1) to establish the usefulness of such satellite systems, (2) to determine system limitations, (3) to assess the effectiveness of such systems in improving existing methods of data collection, (4) to develop water quality instruments which are compatible with a satellite data link and (5) to develop reliable power sources.

Past Activities

Two areas of application have been investigated. One deals with the collection of water quality data; the other deals with the circulation of water in a large lake due to wind-driven currents. Both applications used the Nimbus IRLS system shown in Figure 8. The Nimbus satellite interrogates the IRLS receiver aboard the data collection platform and determines its position as well as recording the output of seven sensors.

Use of the IRLS data relay system aboard Nimbus IV was developed through the instrumentation development arm of EPA. In September of 1971, an IRLS transponder was installed at an EPA monitoring station along the Greater Miami River near Cincinnati, Ohio, and has since been successfully relaying water quality data on pH, conductivity, dissolved oxygen, and temperature. Simultaneous transmission of these parameters via land-line and on-site recordings afforded direct comparison of traditional versus satellite methods.

The second application was developed in conjunction with the Canada Centre for Inland Waters. The IRLS transponder in this case was mounted aboard the free-drifting buoy shown in Figure 9, and was used to chart the wind-driven surface currents by daily fixes by the satellite. Water and air temperatures were also relayed via the system.

Future Satellite for Data Collection Platforms

The ERTS 1 satellite now in orbit, is capable of supporting over 1,000 data collection platforms using a platform transmitter which is very low cost. The ERTS, which can interrogate the platforms every 12 hours, does not have the capability of locating the platform. Nimbus F which is scheduled for launch in mid 1974 will again have the IRLS capability and will be able to support hundreds of platforms. The Synchronous Meteorological Satellite (SMS) which is being developed for NOAA and is scheduled for launch in the second half of 1973 will have the capability to support 10,000 data collection platforms. During any six-hour period, SMS will be capable of collecting data from up to 3,500 different data collection platforms. Therefore, as this brief survey indicates, there will be plenty of opportunity to deploy data collection platforms.

Numerical Modeling of Lake Currents

A numerical model for the quasi-steady wind-driven currents in Lake Erie was developed (reference 1) in conjunction with Case Western Reserve University. A typical result is shown in Figure 10 for a W50S wind at 22.7 mph. The numerical results, which are for a lake with uniform water temperature, were found to compare very favorably with measurements (see Figure 10b) after a fairly steady wind had existed for two days.

A new numerical model which will predict the three dimensional time dependent wind-driven currents and the water temperature is now being developed jointly with Case Western Reserve. Because the spatial distribution of water quality parameters is greatly dependent upon the lake curren this numerical model will be used as an aid in designing methods for remotely sensing total-body water quality.

FUTURE LEWIS RESEARCH CENTER'S REMOTE SENSING PROJECTS

In the previous sections the Lewis Research Center's past and present remote sensing projects have been discussed. These projects represent only a small percentage of the actual remote sensing methods that could be applied to the Great Lakes (see reference 3 for a thorough discussion of possible remote sensing uses for water resources.) Lewis looks to the potential "user" agencies to define their specific needs so that we can plan our future programs to meet these needs. As an aid to the potential "user" agencies for providing an input to Lewis, a summary of the present Lewis remote sensing capabilities is given in Figure 11. If needs of the user agency cannot be met by this capability, additional instrumentation could possibly be acquired or the instrumentation of the other NASA centers could possibly be used.

REFERENCES

1. Gedney, R. T., and Lick, W.: Wind-Driven Currents in Lake Erie, Journal of Geophysical Research, Vol. 77, No. 15, May 20, 1972, pp. 2714-2723.
2. Jirberg, R. J.: An Automatic Underwater Camera System. In Project Hypo, Canada Centre for Inland Waters, Paper No. 6 or U.S. Environmental Protection Agency. Technical Report TS-05-71-208-24, February 1972.
3. Remote Sensing of Pollution. NASA SP-285, 1971.

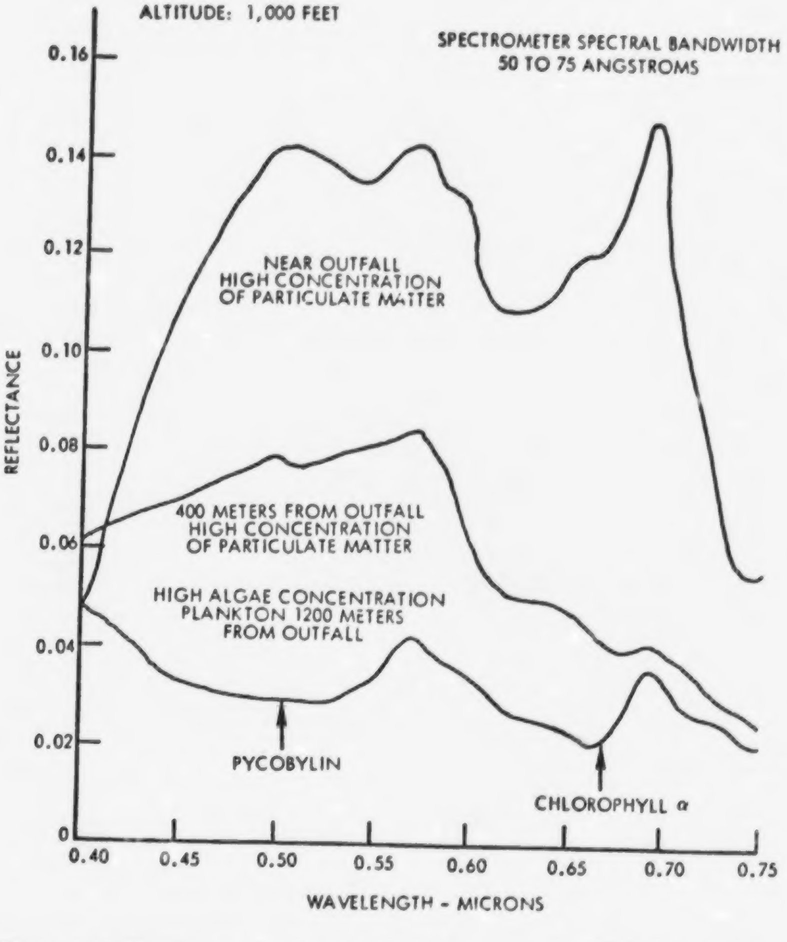


Figure 1: Reflectance vs. wavelength for water measured at 1000 feet altitude, near pollution outfall in Los Angeles area.

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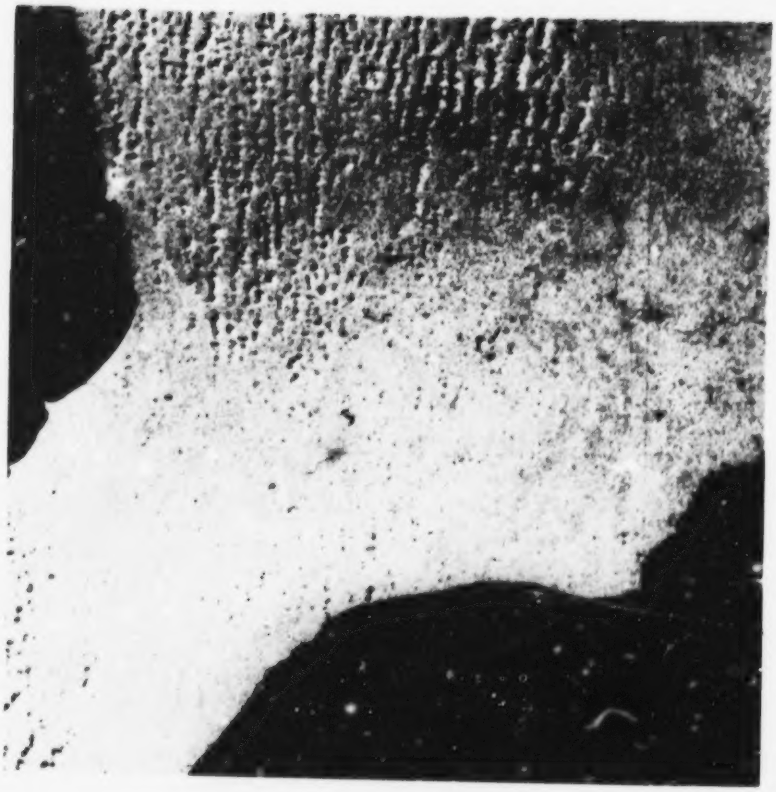

Figure 2a: ERTS MSS Band 7.*

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*Figures 2a--2e are Earth Resources Technology Satellite images of Lake Erie and Lake Huron on September 9, 1972.

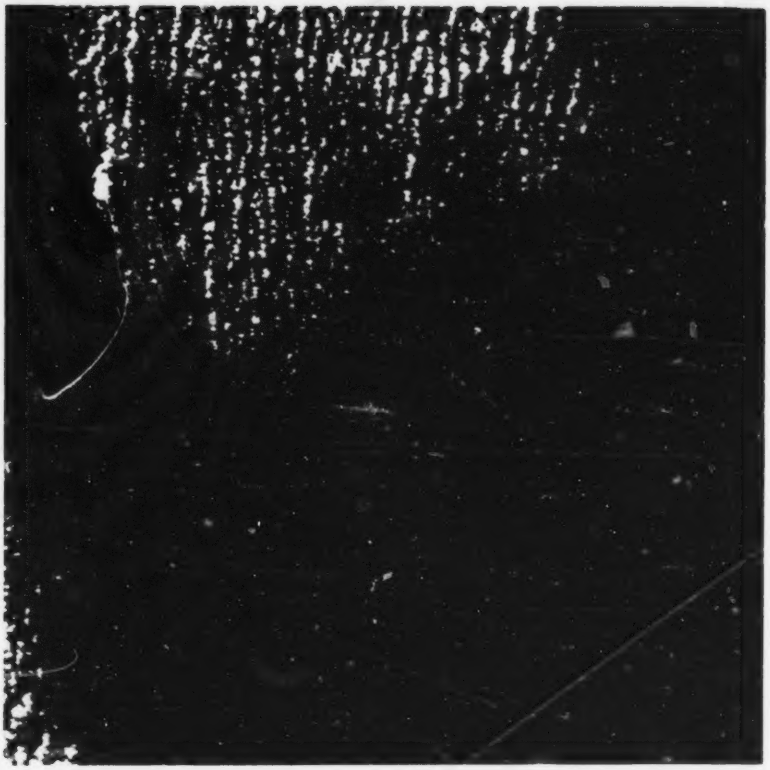

Figure 2b: ERTS MSS Band 5.

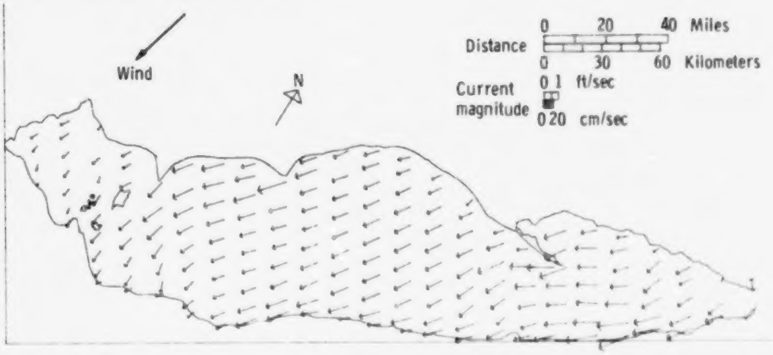
Wind
N
Distance
0 20 40 Miles
0 30 60 Kilometers
Current magnitude
0.1 ft/sec
0 20 cm/sec

Figure 2c: Horizontal velocities at a constant 0.4 M (1.5 ft) from surface. Wind direction, N15E; wind magnitude, 10.1 meters per second (22.7 mph).

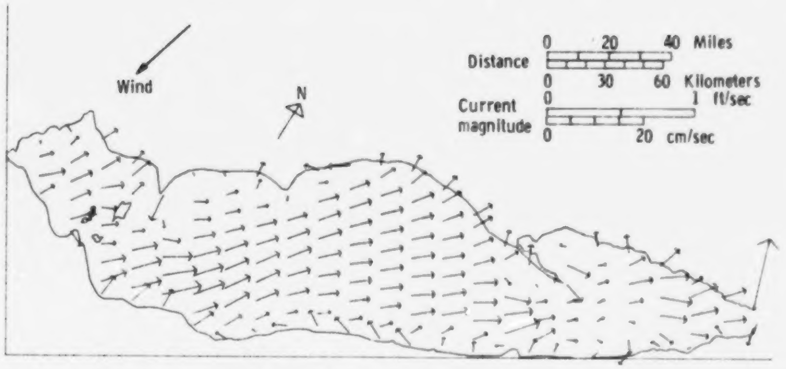
Wind
N
0 20 40 Miles
Distance
0 30 60 Kilometers
Current
magnitude
0 1 ft/sec
0 20 cm/sec

Figure 2d: Horizontal velocities at a constant 1.2 M (4.0 ft) from bottom.

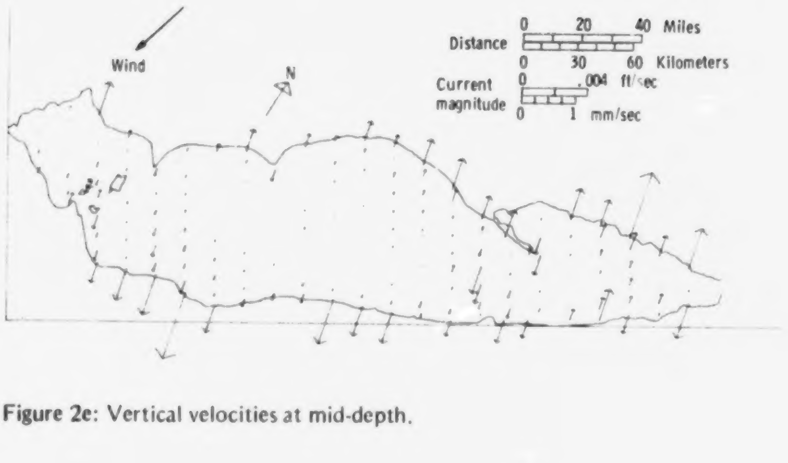
Wind
N
0 20 40 Miles
Distance
0 30 60 Kilometers
Current
magnitude
0 .004 ft/sec
0 1 mm/sec

Figure 2e: Vertical velocities at mid-depth.

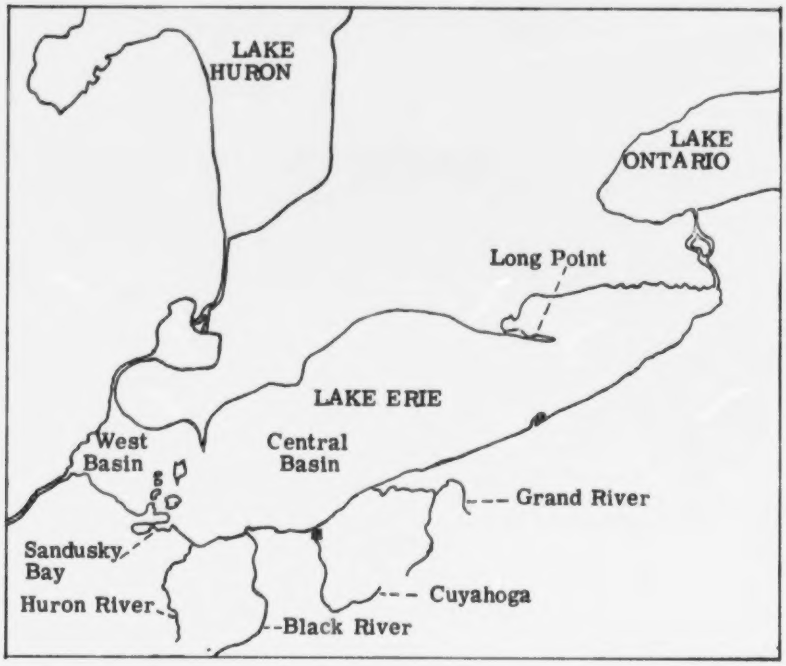
LAKE HURON
LAKE ONTARIO
Long Point
LAKE ERIE
West Basin
Central Basin
Grand River
Sandusky Bay
Cuyahoga
Huron River
Black River

Figure 3: Location map.

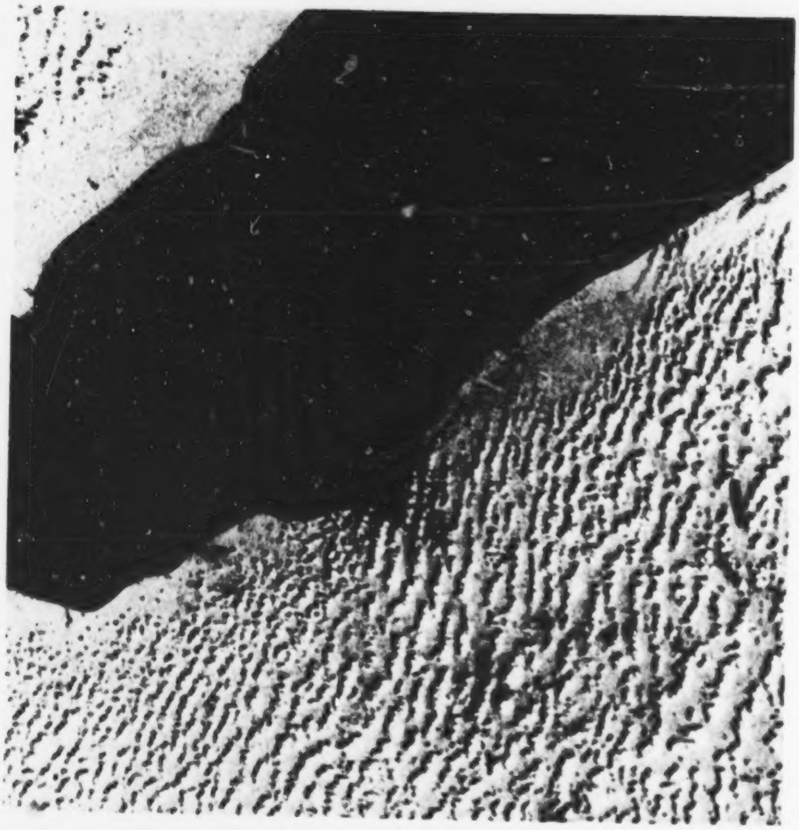

Figure 4a: ERTS MSS Band 7.*

*Figures 4a and 4b are Earth Resources Technology Satellite images of Lake Erie's Central basin on September 9, 1972.

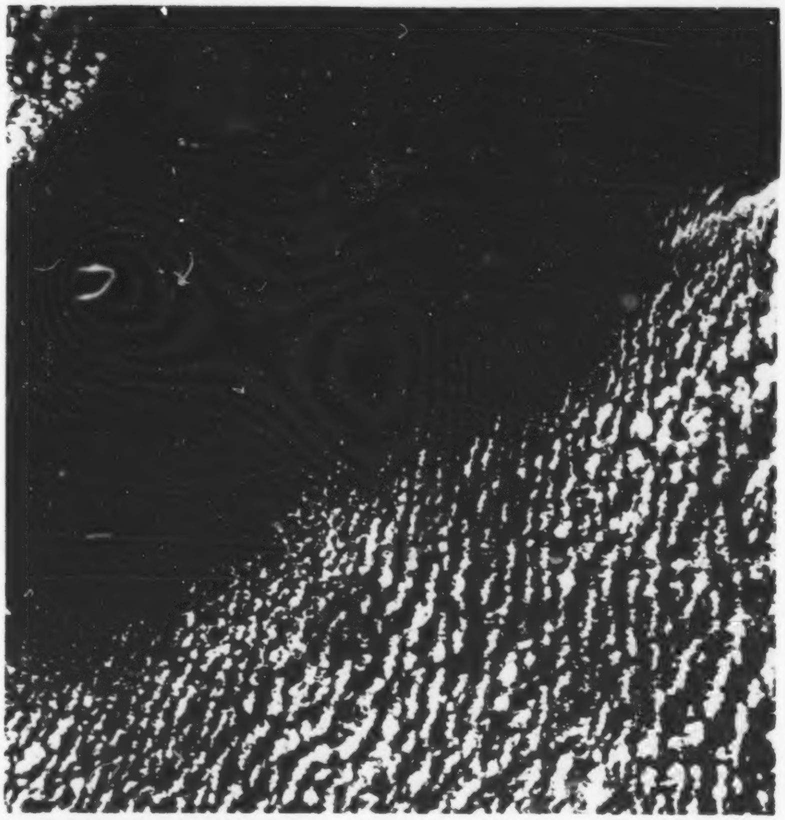

Figure 4b: ERTS MSS Band 5.

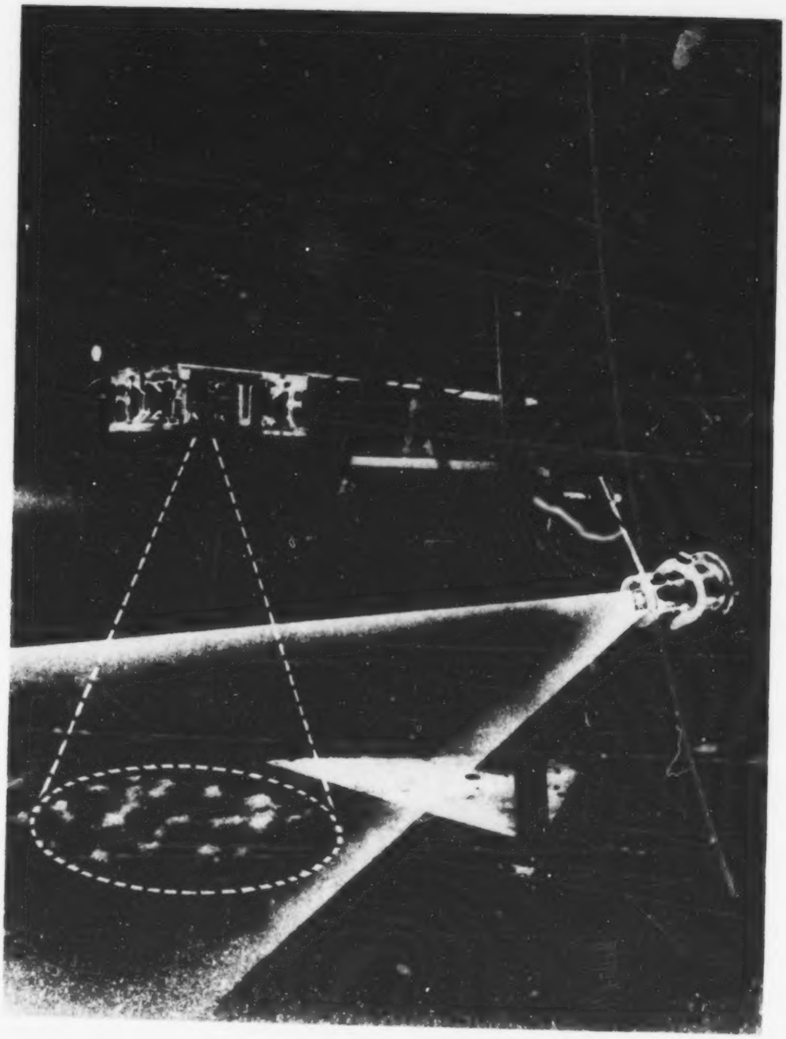

Figure 5: Underwater camera system.

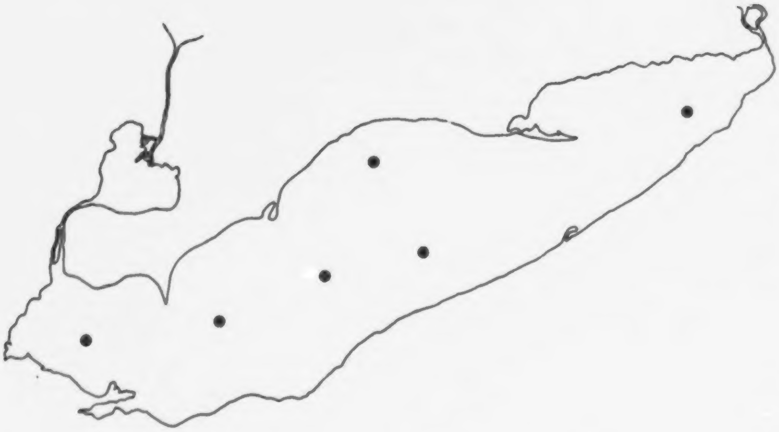

Figure 6: Lake Erie measurement stations of the Canadian *C.S.S. Limnos.*

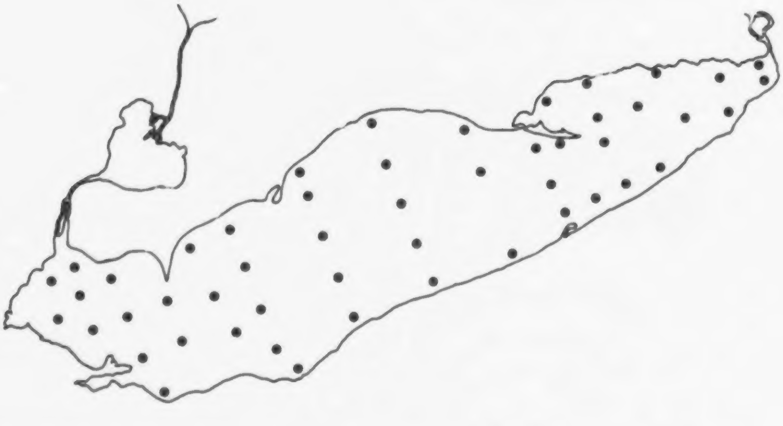

Figure 7: Lake Erie measurement stations of the Canadian *C.M.V. Martin Karlsen.*

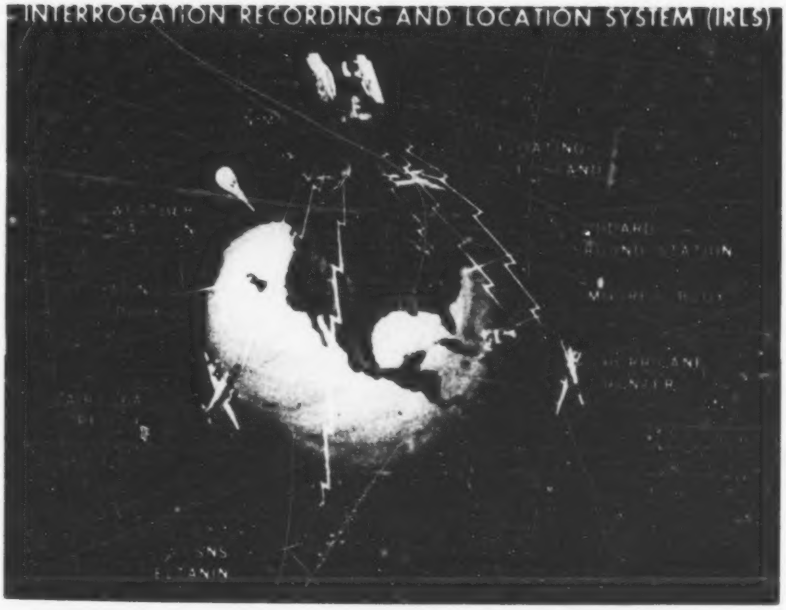
INTERROGATION RECORDING AND LOCATION SYSTEM (IRLS)
FLOATING ISLAND
WEATHER STATION
GODDARD GROUND STATION
MOORED BUOY
HURRICANE HUNTER
USNS ELTANIN

Figure 8: Nimbus IRLS system.

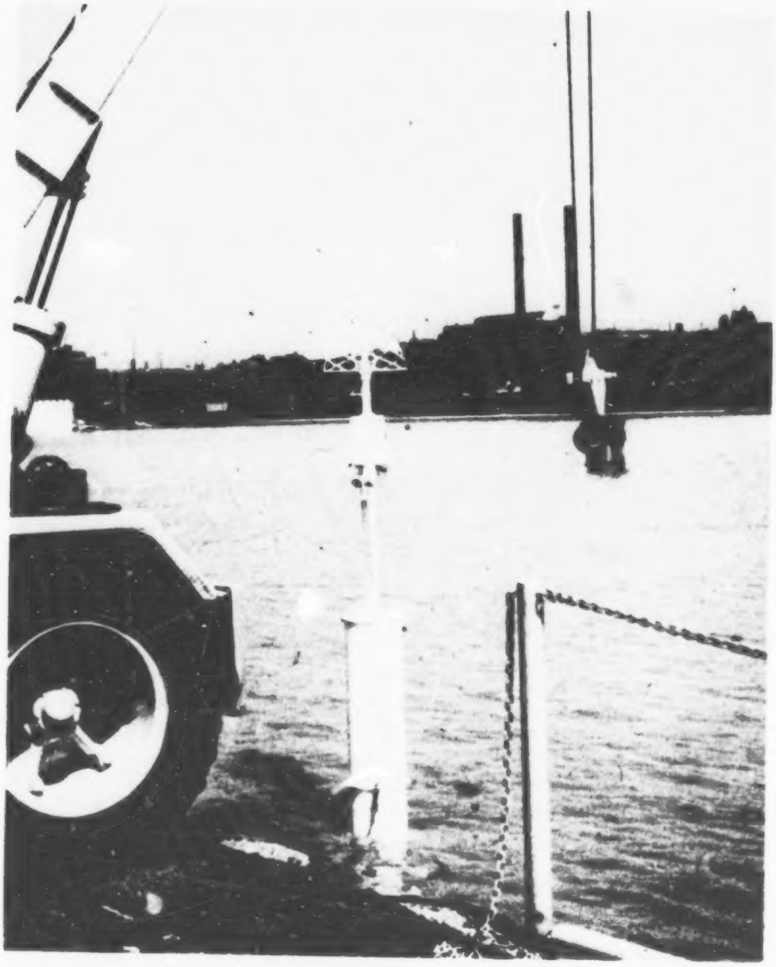

Figure 9: Free drifting buoy with the Nimbus IRLS transponder.

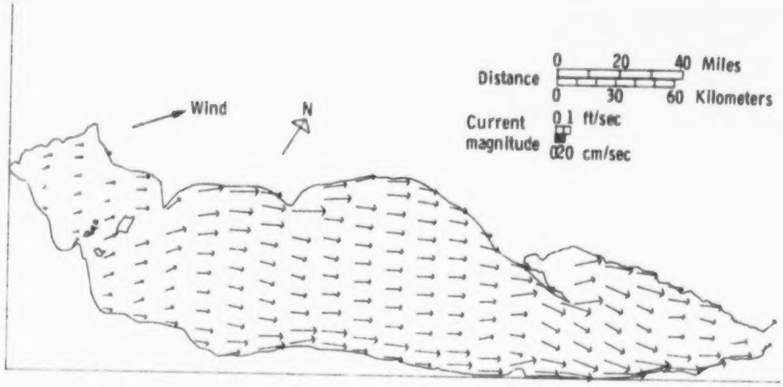
Distance
0 20 40 Miles
0 30 60 Kilometers
Current magnitude
0 1 ft/sec
0 20 cm/sec
Wind
N

Figure 10a: Horizontal velocities at a constant 0.4 m (1.5 ft) from surface. Wind direction, W50S: wind magnitude, 10.1 meters per second (22.7 mph).*

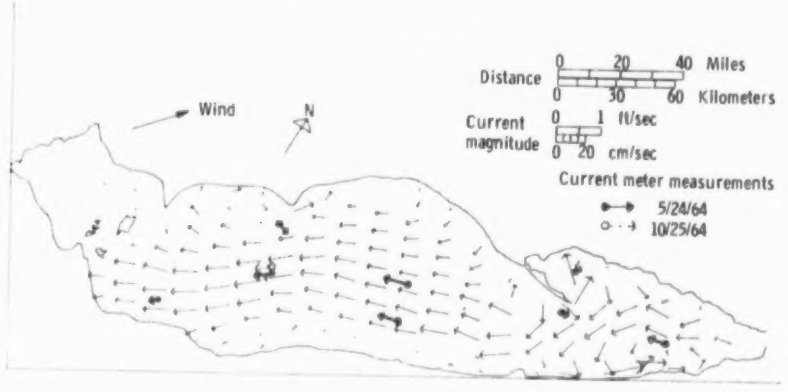
Distance
0 20 40 Miles
0 30 60 Kilometers
Current magnitude
0 1 ft/sec
0 20 cm/sec
Current meter measurements
5/24/64
10/25/64
Wind
N

Figure 10b: Horizontal velocities at a constant 9.9 M (32.8 ft) from surface. Wind direction, W50S: wind magnitude, 10.1 meters per second (22.7 mph).*

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*Figures 10a and 10b are Lake Erie Wind-Driven Currents.

LEWIS RESEARCH CENTER'S REMOTE SENSING CAPABILITY

1. AIRCRAFT
   - (A) DC-3
   - (B) OV-1B/GRUMMAN MOHAWK (A TWIN TURBOPROP AIRCRAFT WHICH CARRIES A PILOT PLUS OBSERVER)
2. INSTRUMENTATION FOR REMOTE MEASUREMENTS
   - (A) MULTIBAND CAMERA SYSTEM (BOTH 35MM NIKONS AND 70MM HASSELBLAD CAMERAS)
   - (B) 9" × 9" KC-1B FAIRCHILD MAPPING CAMERA
   - (C) BARNES PRT-5 (PRECISION RADIATION THERMOMETER FOR MEASURING SURFACE TEMPERATURE)
   - (D) AN/APS 94-C SIDE-LOOKING RADAR (PROVIDES IMAGES 50, 100 OR 180 KILOMETERS WIDE)
   - (E) INFRARED THERMAL IMAGER (PROVIDES AN IMAGE FROM WHICH THE SURFACE TEMPERATURE MAY BE RESOLVED WITHIN .3°C)
   - (F) FILTER WEDGE SPECTROMETER
   - (G) MODULAR MULTISPECTRAL SCANNER (A BENDIX M^2S IS BEING ACQUIRED WHICH WILL PROVIDE AN IMAGE FROM EACH OF 13 BANDWIDTH CHANNELS)
3. SATELLITE RECEIVING STATION

   CAPABLE OF RECEIVING AUTOMATIC PICTURE TRANSMISSIONS FROM SUCH SATELLITES AS NIMBUS, ATS, AND ITOS

Figure 11.

Great Lakes Research From the United States Coast Guard's Point of View

Dr. Charles C. Bates, Chief Scientist, Office of Research and Development, United States Coast Guard, Department of Transportation

ABSTRACT

The Great Lakes, as the world's largest group of inland freshwater lakes, provide an extensive theater of operations for the United States Coast Guard's Ninth District with headquarters at Cleveland, Ohio. Throughout this nearly 1,000 mile-wide District which extends from Duluth as far east as St. Regis, New York, on the St. Lawrence River, the Coast Guard operates two icebreakers (the *Mackinaw* and the *Edisto*), seven buoy tenders, five tugs, 46 shore stations, and 34 manned lighthouses. Prior to 1971, Coast Guard research activities in the Great Lakes have been primarily restricted to providing ship and aircraft support time to such organizations as the University of Wisconsin and the Great Lakes Survey. With the advent in 1970 of the Congressionally-authorized three-year "Winter Navigation Program" under the leadership of the U.S. Army Corps of Engineers, the Coast Guard has been developing and testing new methods of ice navigation, including icebreaking techniques and improved wintertime aids to navigation. Supporting research is also underway into the related conditions of the ice cover, including windrows and "mush" ice, while field studies utilizing side-looking radar as an all-weather ice reconnaissance technique have been recently completed.

As the result of new legislation directed towards marine environmental protection, namely the Water Quality Act of 1970, its 1972 amendment, and the Port and Waterways Safety Act of 1972, the Coast Guard is very deeply involved in the detection of pollution whether by ship sewage or other hazardous polluting substances, the cleanup of pollution resulting from ship collisions or groundings, and the prevention of pollution by improved on-board treatment processes, by improved navigational aids, by use of vessel traffic systems, and by improved ship design.

During 1973 the Coast Guard will base an HU-16 pollution patrol aircraft at Traverse City, Michigan, equipped with infrared and ultraviolet scanners. Programmed for about 600 flight hours annually, this aircraft will fly about 90,000 miles of pollution patrol per year over the Great Lakes. Although the sensors are being operated for law enforcement purposes, raw data derived from them may be of interest to limnologists studying physical processes of the Great Lakes.

At the moment, the Coast Guard's parent organization, the Department of Transportation, has no marine research underway pertinent to the Great Lakes. However, the St. Lawrence Seaway Development Corporation, another component of the DOT, is participating in the earlier mentioned "Winter Navigation Program" coordinated by the U.S. Army Corps of Engineers. The Corporation's main interest lies in ice information, control, and engineering, particularly with respect to improving the design of ice-stabilizing structures for the St. Lawrence River that would facilitate winter navigation but avoid interference with hydroelectric power operations.

* * *

The Great Lakes, as the world's largest group of inland lakes, provide an extensive theater of year-round operations for the Ninth District of the United States Coast Guard. Commanded by Rear Admiral A. A. Heckman, USCG, from headquarters in Cleveland, Ohio, this District extends for nearly a thousand miles from Duluth in the west to St. Regis, New York, on the St. Lawrence River in the east. In these waters, the Coast Guard operates two ice breakers, seven buoy tenders, five tugs, 46 shore stations, and 34 manned lighthouses, as well as three air stations at Detroit, Michigan, Traverse City, Michigan, and Chicago, Illinois. (see Appendix I for a comprehensive listing of facilities). The 2752 men and women of this command provide a multi-faceted package of marine services, including search and rescue, aids to navigation, domestic ice navigation, marine law enforcement, merchant marine safety, recreational boating safety, marine environmental protection, and oceanographic/meteorological support services.

Coast Guard research pertinent to the Great Lakes is conducted in two different modes, first, by providing aircraft and ship support services to other qualified organizations interested in conducting acutal marine research themselves, and second, by performing field research under the direction of its own in-house staff. In the first mode, aircraft and ship support services are provided to such organizatons as the Great Lakes Survey for aerial ice reconnaissance studies, to the National Ocean Survey for the International Field Year for the Great Lakes, and to the University of Wisconsin for research cruises pertaining to the marine geology of Lakes Michigan and Superior. These services are provided in accordance with several statutory guidelines, the most pertinent of which may be Section 94 of Title 14; U.S. Code, which states:

"94. Ocenographic research:

The Coast Guard shall conduct such oceanographic research, use such equipment or instruments, and collect and analyze such oceanographic data, in cooperation with other agencies of the Government, or not, as may be in the national interest."

Until September, 1972, when the Coast Guard Research and Development Center was established at Groton, Connecticut, all in-house Great Lakes research was planned and implemented by Washington-based Coast Guard staff. This research effort has been primarily directed toward improving ice navigation during the winter months (see Figure 1). For example, since 1969,

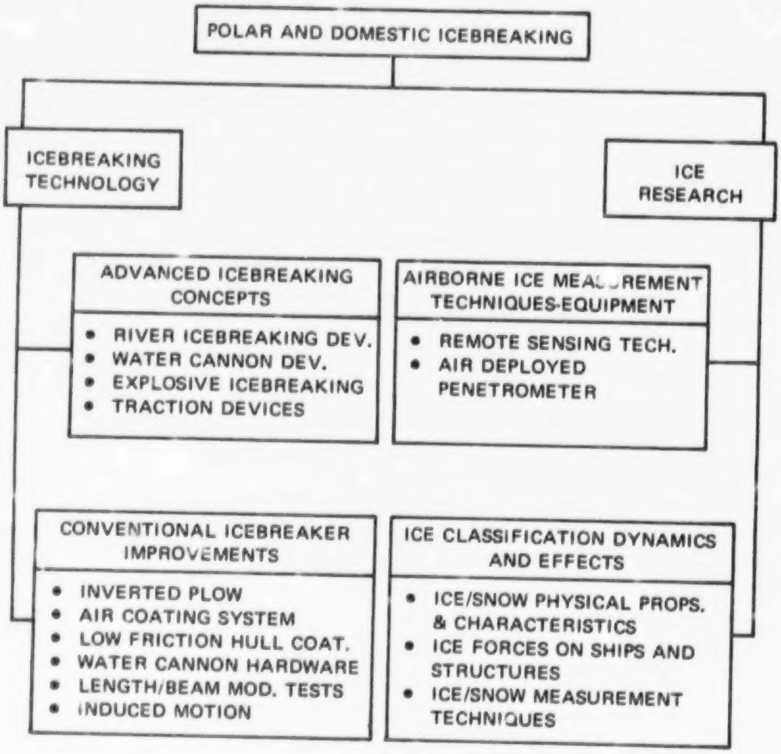
POLAR AND DOMESTIC ICEBREAKING
ICEBREAKING TECHNOLOGY
ICE RESEARCH
ADVANCED ICEBREAKING CONCEPTS
• RIVER ICEBREAKING DEV.
• WATER CANNON DEV.
• EXPLOSIVE ICEBREAKING
• TRACTION DEVICES
AIRBORNE ICE MEASUREMENT TECHNIQUES-EQUIPMENT
• REMOTE SENSING TECH.
• AIR DEPLOYED PENETROMETER
CONVENTIONAL ICEBREAKER IMPROVEMENTS
• INVERTED PLOW
• AIR COATING SYSTEM
• LOW FRICTION HULL COAT.
• WATER CANNON HARDWARE
• LENGTH/BEAM MOD. TESTS
• INDUCED MOTION
ICE CLASSIFICATION DYNAMICS AND EFFECTS
• ICE/SNOW PHYSICAL PROPS. & CHARACTERISTICS
• ICE FORCES ON SHIPS AND STRUCTURES
• ICE/SNOW MEASUREMENT TECHNIQUES

Figure 1: U.S. Coast Guard research and development efforts during FY 1973 pertinent to navigation of the Great Lakes when ice covered.

The Coast Guard, under the technical direction of LCDR J.A. McIntosh, USCG, has been overflying different kinds of ice with an AN/DPD-2 side-looking radar (SLAR) originally developed by Philco-Ford as an Army drone radar. The operating frequency of the radar is K Band (16.5 khz) with an antenna beamwidth of 0.4 azimuth cscp cos 1/2 0 elevation. When flown at an altitude of about 8,000 feet (2,400 m), a 10-mile (16 km) swath is observed on each side of the aircraft, and imagery is recorded on a 5-inch (12.5 cm) wide film at a scale of about 1:350,000.

During February-March 1971, this radar and a photographic mapping camera were mounted in a Coast Guard C-130 "Hercules" aircraft and flown over the general confluence area of Lakes Superior, Huron, and Michigan. The purpose was to develop signatures for interpretation of Great Lakes ice cover and for investigating the effect of snow cover on these signatures. The camera used was a standard T-11 mapping frame camera with a 6-inch focal length that gave a scale of about 1:15,000 at flight altitude. Analysis of the flight lines, supplemented by experience acquired during similar remote sensing in the North American Arctic leads to the conclusion that SLAR is probably the most useful tool available today for periodic, all-weather, day/night coverage of ice.[1] Slush, frazil and grease ice sometimes could not be differentiated on the Great Lakes, or, on certain occasions, even detected in open water. Young ice, although readily detectable, could not generally be separated into dark gray and gray-white types. Winter ice could be interpreted with relative ease, including crack and ridge systems. Snow cover on lake ice tends to complicate the identification of ice types, and additional field research needs to be done under controlled, well-monitored conditions.

In the technology area, improvement of conventional icebreaker capability and development of advanced icebreaking concepts have been underway for the past two years. Projects of a relatively short-range scope are specifically directed towards providing minimum hull and machinery modifications to the existing icebreaking fleet and realizing significant increases in capability. These concepts include an air bubbler hull lubrication system, low friction hull coating development, induced motion effects, and an inverted plow. Presently, an air bubbler system is being installed on the *CGC Sundew* (180 foot class buoy tender) for tests in mush ice and plate ice in Lake Michigan based on last winter's tests aboard the *CGC Raritan* (110 ft. tug). Newly developed low friction hull coatings are now being tested at Rensselaer Polytechnic Institute, while a finite element analysis study on pitching systems is being done for the Coast Guard by the University of Wisconsin under a National Science Foundation grant.

In the area of advanced icebreaking concepts, several subsystems are being developed for incorporation into a unique hull which displaces cut ice plates under the fixed ice at either side of the channel being cleared. The goal of this unique icebreaker will be to clear an open channel with a minimum amount of energy. The subsystems are mechanical cutters, water jet cutters, and a traction system. This new icebreaker presently exists as a 1/6 scale model (24 feet) and is in its second year of testing, with a full scale prototype planned for construction in early FY 1975. A different concept was also tested last winter off Muskegon, Michigan, that of explosive icebreaking using the "Repetitive Explosive Device for Soil Disposal" concept patented by the Southwest Research Institute. This approach used frequent detonation of a propane-air mixture released beneath the ice from a ram-like underwater bow. Effective removal of the broken ice, however, proved to be a major problem.

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[1] "Analysis of SLAR Imagery for Arctic and Lake Ice," Raytheon Company Report DOT-CG-14486A, Raytheon Company, Wayland, Mass., 168 pages, March, 1972.

One of the interesting and largely unsolved icebreaking problems of the Great Lakes is how to steadily penetrate "mush" or "ice cream" ice, i.e., a heavy-rafted, brash ice as much as 12 feet thick. For example, in one case, during the winter of 1971, when the *CGC Mackinaw* was escorting a car ferry beset in Muskegon, Michigan's harbor, the icebreaker became continually stuck in such ice as the result of large amounts of "dry" frictional force. It required about seven minutes to break loose each time, making a total ramming cycle good for about 133 feet of penetration which would last about 12 minutes during which the ship was actually stuck about 58% of the time. Model work to date suggests that smooth hull coatings may be the answer to this type of problem. However, a significant effort is still necessary to better describe and characterize the physical properties of these mush ice fields. In fact, careful mathematical characterization of all types of ice cover in the Great Lakes is one of the Coast Guard's continuing research projects; the status of this effort will be reported by Dr. J. P. Welsh, of the Coast Guard's Research & Development Center.

As already reported by the U.S. Army Corps of Engineers, the Coast Guard also plays an active role in the Extended Navigation Season Demonstration Program for the Great Lakes and the St. Lawrence Seaway sponsored by the Corps. In this program, the Coast Guard is assessing survival equipment for shipboard use, testing modified radio beacons for optimum time of detection versus radar bandwidth, testing new ice buoy concepts, including anchors, mooring chains, and ice shedding superstructures, experimenting with a "wire-in-the-sky" concept using a laser beam for channel marking, and, with the Corps of Engineers, developing and testing a combined air bubbler-wire guidance system in Whitefish Bay of upper Michigan.

As a result of new legislation, namely, the Water Quality Act of 1970 and its 1972 amendment, and the Port and Waterways Safety Act of 1972, as well as the Canadian-United States agreement of April, 1972, relative to Great Lakes water quality, the Coast Guard is also very deeply involved in all aspects of marine environmental protection. A broad spectrum of research and development efforts, the end-products of which will be available for use by Coast Guard units on the Great Lakes, are underway in the following areas: (1) detection of pollution-caused ship sewage, oil, and hazardous polluting substances; (2) control and cleanup of pollution resulting from ship collisions or groundings, including development under contract with Arthur D. Little Company, of a Chemical Hazards Response Information System (CHRIS), and (3) prevention of pollution by improved on-board treatment processes, by improved navigational aids, by use of vessel traffic systems, and by improved ship design.

Also of interest to other federal agencies operating on the Great Lakes is that during 1973 the Coast Guard will base an HU-16 pollution patrol aircraft at Traverse City, Michigan. This aircraft will be flying about 90,000 miles of pollution detection; its sensor package consists of a state-of-the-art infrared line scanner operating in the 8 to 13 micron band and an ultraviolet line scanner operating in the 0.3 to 0.4 micron band. Signals derived from these detectors will be processed by a gyro-controlled roll compensator and presented in real-time on a direct-view storage tube with the data written line-by-line across the face of the tube. Each scanner subsystem will link to a strip film recorder which reproduces the detected signal on 70-mm film; means are also provided for recording image and synchronization data on magnetic tape. Although these sensors will be operated for law enforcement purposes, raw data derived from the flights may well be of interest to limnologists studying physical processes in the areas being overflown.

As of the present time, the Coast Guard's parent organization, the Department of Transportation, has no marine research underway that is pertinent to the Great Lakes. In fact, the Department's program for university research was announced only this past September, and the first proposals resulting therefrom were due on December 1, 1972. However, the St. Lawrence Seaway Development Corporation, another component of the Department, also participates in the earlier mentioned "Winter Navigation Program" coordinated by the U.S. Army Corps of Engineers. The Corporation's effort is directed towards aerially mapping the icecovered United States portion of the Seaway by flights that may be as often as weekly, extending from Cornwall Island to eastern Lake Ontario. Regular observations of surface ice characteristics, supplemented by air/water temperature and solar radiation readings, are being used by the Corporation to compile ice formation and decay profiles relative to the ice cover of the St. Lawrence River. The Corporation also is generating improved designs for ice-stabilizing structures that would provide better methods for facilitating winter navigations while avoiding interference with hydroelectric power operations. Likewise, in-house experiments are being conducted with polyethylene foam planks floating on the downstream guide wall of the Snell Lock to determine the possibility of inhibiting the buildup of ice around hydraulic structures during below freezing temperatures.

In summary, the Coast Guard's in-house research effort on the Great Lakes is modest and confined to improving wintertime operations. However, the Coast Guard has a well-earned tradition of assisting other federal agencies with ships and aircraft in the pursuit of their research whenever the workload permits. This tradition will continue and contribute markedly to that concept dear to all program managers, namely, cost-effectiveness.

Appendix I: United States Coast Guard Facilities—Ninth District

GREAT LAKES ICE BREAKERS

NAME	CLASS	HP	NORMALLY DEPLOYED
CGC ARUNDEL (HOMEPORT CHICAGO, ILLINOIS)	WYTM	1000 SHP	SOUTHERN LAKE MICHIGAN, CENTRAL LAKE MICHIGAN
CGC BRAMBLE (HOMEPORT DETROIT, MICHIGAN)	WLB	1200 SHP	ST. CLAIR R., DETROIT R., LAKE ST. CLAIR, TOLEDO, BUFFALO
CGC ACACIA (HOMEPORT PORT HURON, MICHIGAN)	WLB	1200 SHP	DETROIT R., LAKE ST. CLAIR, SOUTHERN LAKE HURON
CGC KAW (HOMEPORT CLEVELAND, OHIO)	WYTM	1000 SHP	DETROIT RIVER, CLEVELAND, BUFFALO, TOLEDO
CGC MACKINAW (HOMEPORT CHEBOYGAN, MICHIGAN)	WABG	10,000 SHP	STRAITS OF MACKINAW, ST. MARYS RIVER, WHITEFISH BAY
CGC MESQUITE (HOMEPORT STURGEON BAY, WISCONSIN)	WLB	1200 SHP	GREEN BAY, LITTLE BAY DE NOC, STURGEON BAY
CGC NAUGATUCK (HOMEPORT SAULT STE. MARIE, MICHIGAN)	WYTM	1000 SHP	ST. MARYS RIVER, WHITEFISH BAY
CGC OJIBWA (HOMEPORT BUFFALO, NEW YORK)	WYTM	1000 SHP	BUFFALO, EASTERN LAKE ERIE
CGC RARITAN (HOMEPORT GRAND HAVEN, MICHIGAN)	WYTM	1000 SHP	LAKE MICHIGAN, GREEN BAY, GRAND TRAVERSE BAY
CGC SUNDEW (HOMEPORT CHARLEVOIX, MICHIGAN)	WLB	1800 SHP	STRAITS OF MACKINAW, GRAND TRAVERSE BAY, L. MICHIGAN, GREEN BAY
CGC WOODRUSH (HOMEPORT DULUTH, MINNESOTA	WLB	1200 SHP	WESTERN LAKE SUPERIOR, WHITEFISH BAY
CGC SOUTHWIND (HOMEPORT MILWAUKEE, WISCONSIN)	WAGB	10,000 SHP	ST. MARYS RIVER, STRAITS OF MACKINAW, WHITEFISH BAY

Legend:

WYTM	– 110 FT HARBOR TUB
WAGB	– MACKINAW, WIND CLASS ICEBREAKER
WLB	– BUOY TENDER 180 FT

Appendix II: Facilities of U.S. Coast Guard Ninth District

GROUPS

Buffalo, New York
Detroit, Michigan
Duluth, Minnesota
Sault Ste. Marie, Michigan
Milwaukee, Wisconsin
Muskegon, Michigan

STATIONS

STA Alexandria Bay, Alexandria Bay, New York
STA Ashtabula, Astabula, Ohio
*STA Belle Isle, Detroit, Michigan
*STA Calumet Harbor, Chicago, Illinois
*STA Charlevoix, Charlevoix, Michigan
*STA Cleveland Harbor, Cleveland, Ohio
*STA Duluth, Duluth, Minnesota
STA Erie, Erie, Pennsylvania
STA Fairport, Grand River, Ohio
*STA Frankfort, Frankfort, Michigan
*STA Grand Haven, Grand Haven, Michigan
*STA Grand Marais, Grand Marais, Michigan
*STA Harbor Beach, Harbor Beach, Michigan
STA Holland, Holland, Michigan
*STA Kenosha, Kenosha, Wisconsin
*STA Lorain, Lorain, Ohio
*STA Ludington, Ludington, Michigan
STA Manistee, Manistee, Michigan
*STA Marblehead, Marblehead, Ohio
STA Marquette, Marquette, Michigan
*STA Michigan City, Michigan City, Indiana
*STA Milwaukee, Milwaukee, Wisconsin
STA Munising, Munising, Michigan
STA Muskegon, Muskegon, Michigan
STA Niagara, Youngstown, New York
STA North Superior, Grand Marais, Minnesota
STA Oswego, Oswego, New York
*STA Port Huron, Port Huron, Michigan
STA Portage, Hancock, Michigan
STA Racine, Racine, Wisconsin
STA Rochester, Rochester, New York
*STA Saginaw River, Bay City, Michigan
STA Sandusky Bay, Sandusky, Ohio
STA Sheboygan, Sheboygan, Wisconsin
STA Sodus, Sodus Point, New York
*STA South Haven, South Haven, Michigan

Appendix II: (Continued)

STATIONS (Cont.)

*STA St. Clair Flats, Harsens Island, Michigan
*STA St. Clair Shores, St. Clair Shores, Michigan
*STA St. Ignace, St. Ignace, Michigan
STA St. Joseph, St. Joseph, Michigan
*STA Sturgeon Bay Canal, Sturgeon Bay, Wisconsin
*STA Tawas, East Tawas, Michigan
*STA Toledo, Toledo, Ohio
STA Two Rivers, Two Rivers, Wisconsin
STA Wilmette Harbor, Wilmette, Illinois

LIGHT ATTENDANT STATIONS

LASTA Cape Vincent, Cape Vincent, New York
*LASTA Cheboygan River, Cheboygan, Michigan
LASTA Fox River, Menasha, Wisconsin

LIGHT STATIONS

LTSTA Algoma, Algoma, Wisconsin
*LTSTA Alpena, Alpena, Michigan
LTSTA Big Sable, Ludington, Michigan
LTSTA Eagle Harbor, Eagle Harbor, Michigan
*LTSTA Escanaba, Escanaba, Michigan
LTSTA Indiana Harbor, Indiana Harbor, Indiana
LTSTA Kewaunee, Kewaunee, Wisconsin
LTSTA Keweenaw Lower Entrance, Lake Linden, Michigan
*LTSTA Manitowoc, Manitowoc, Wisconsin
LTSTA Menominee, Menominee, Wisconsin
LTSTA Point Betsie, Frankfort, Michigan
LTSTA Port Washington, Port Washington, Wisconsin
*LTSTA Presque Isle, Presque Isle, Michigan
LTSTA Rawley Point, Two Rivers, Wisconsin
LTSTA Sherwood Point, Sturgeon Bay, Wisconsin
LTSTA Tibbetts Point, Cape Vincent, New York
*LTSTA Two Harbors, Two Harbors, Minnesota

CAPTAINS OF THE PORT

Buffalo, New York
Chicago, Illinois
Cleveland, Ohio
Detroit, Michigan
Duluth, Minnesota
Milwaukee, Wisconsin
Sault Ste. Marie, Michigan
Toledo, Ohio

Appendix II (Continued)

AIR STATIONS

USCG Air Station Traverse City
Traverse City, Michigan 49684

USCG Air Station Detroit
Selfridge AFB
Detroit, Michigan 48045

USCG Air Station Chicago
Glenview, Illinois 60026

TOTAL NUMBER OF PERSONNEL IN NINTH COAST GUARD DISTRICT

Civilian	192
Officers	312
Enlisted	2248
Total	2752

*ice reporting stations

Ice Properties and Their Relation to Ship Transit in the Great Lakes

James P. Welsh, Jr., Chief, Ice Research, Research and Development Center, United States Coast Guard, Department of Transportation

ABSTRACT

Adequate information on the physical properties of lake ice relevant to the ship-ice interaction for domestic icebreaker engineering is not presently available.

In response to this need the Coast Guard ice research program is directly concerned with the identification and quantification of the physical properties of ice which affect ship transit. Physical properties, such as the flexural strength, coefficients of static and kinetic friction, density, thermal characteristics of the ice column, and the areal distribution and thickness are the properties presently under investigation.

Field experiments were conducted on the ice at various locations in the Great Lakes during winter 1972. All measurements obtained thus far have been in-situ field determinations.

Preliminary results indicate that the frequency distributions of the measurement values obtained for all the physical properties as above are not normal distribution functions. The consequence of this observation is that descriptive statistics like the arithmetic mean and standard deviation could be misleading if used as representative numbers for substitution in various equations for engineering purposes. Alternative descriptive statistics of central tendency and dispersion are considered and partially evaluated. Analysis of variance techniques, both parametric and nonparametric, have been used where appropriate as determined by examination of the relevant assumptions to assess the character of the observed variation. Recommendations based on the present conclusions are to continue the 1972 work during winter 1973 with increased measurement precision and experimental control as primary objectives.

* * *

INTRODUCTION

The U.S. Coast Guard has as one of its missions the responsibility to provide navigational assistance in ice covered waters. The scene for operations may be in the Great Lakes, the U.S. river systems, or the polar regions.

Through the years the Coast Guard has approached the problems encountered with a continuing research effort. One facet of this research effort is concerned with the identification and quantification of the physical properties of ice which affect ship transit. Various papers are presented in the literature (Kashteljan, et. al. 1968, Lewis, et. al. 1970) which identify physical properties important to understanding ice resistance to ship motion. Investigation of some of the physical properties of lake ice is the subject of this progress report. The preliminary analysis of measurements made in-situ of flexural strength and ice thickness during winter 1972 is presented. Additional properties were investigated as cited in the descriptive abstract and will be reported in a future publication.

EXPERIMENTAL DESIGN

This portion contains a statement of the objectives of the investigation, a description of the experimental techniques, and an outline of the analytical techniques to be applied to the results.

Objectives

The objectives are to obtain numerical estimates of the flexural strength of lake ice and representative measurements of ice thickness as they relate to full-scale icebreaker test and evaluation.

There are, of course, many possible souces of variation inherent in measurements of the above two physical properties. Some of these sources might be considered by "blocking," as in a block design. For example, when an ice beam is failed as a cantilever, the upper fiber is in tension. The growth of the ice may have been such that the strength in tension is greater along one direction than along another. If this were the case, then sets of ice beams could be tested where all the beams in one set are oriented in one direction. Unfortunately, to arrive at a definitive answer to the question of whether the orientation of an in-situ cantilever ice beam effects the determined flexural strength, requires a reasonably sophisticated experiment not easily performed in the field.

Previous ice strength work (Frankenstein 1959, 1961) indicated some dependence on ice temperature and time of day. These two additional sources of variation can also be considered by use of a block design. However, the temperature problem is somewhat more difficult to deal with because of measurement technique. For example, if an ice beam is failed in the push down mode, the temperature distribution (vertical) in the upper fiber will, in combination with ice crystal alignment, effect the assumption that each layer may move freely relative to an adjacent layer, if indeed the ice is layered. The temperature measurement problem has not been satisfactorily solved. There are many more possible sources of variation, some known and some unknown, some measurable and some not. Future reports will consider these problems more fully.

Experimental Techniques

The flexural strength of the ice was measured by failing in-situ cantilever beams. An in-situ cantilever beam was used considering the action of a vessel moving through an ice field. The beams were normally failed in the push down mode. The flexural strength of an ice beam was determined by the following relationship:

$$\sigma_f = \frac{6kPl}{bh^2}$$

where σ_f is the flexural strength, k is a constant dependent on the surface area of a particular ram, P is the load, l is the beam length, b is the beam width, and h is the beam thickness.

The assumptions which are pertinent for the determination of flexural strength are as follows:

(1) The material is homogeneous; that is, it obeys Hooke's law.
(2) Stresses are within the elastic limit.
(3) Every layer of the material is free to expand or contract as if separate from other layers.
(4) The tensile and compressive moduli of elasticity are equal.
(5) The cross section remains a plane surface.

These assumptions were not tested in the initial field investigation. Some of them will be examined in detail during the field experiments planned for winter 1973. Detailed discussion of ice beam preparation is contained in an internal Coast Guard document which is being prepared for publication.

The thickness measurements were obtained in two ways:

(1) Small holes were drilled through the ice and a tape marked in centimeters with a toggle arrangement was lowered through the hole, then pulled up until the toggle engaged the lower surface of the ice. The thickness of the ice was then read directly at the upper surface.

(2) When a cantilever beam was broken, a number of thickness measurements would be made using a specially adapted meter stick.

Figures 1 through 5 illustrate the general scene for the ice property measurements.

Figures 6 through 12 present graphic data reduction and tests.

Analytical Techniques

For the purpose of this study, lake ice is considered as a subpopulation to distinguish it from other ice types, sea ice, for example. Because the conclusions of this study are based on statistical techniques of analysis, a discussion of the assumptions made and how violation might effect the results is presented.

Measurements on a sample are subject to variation arising from unknown and known sources. In order to avoid bias in selecting the samples, it is common practice to select the samples in a random manner. The purpose of

Figure 1: Measuring ice thickness.

Figure 2: Initial cutting of an ice beam.

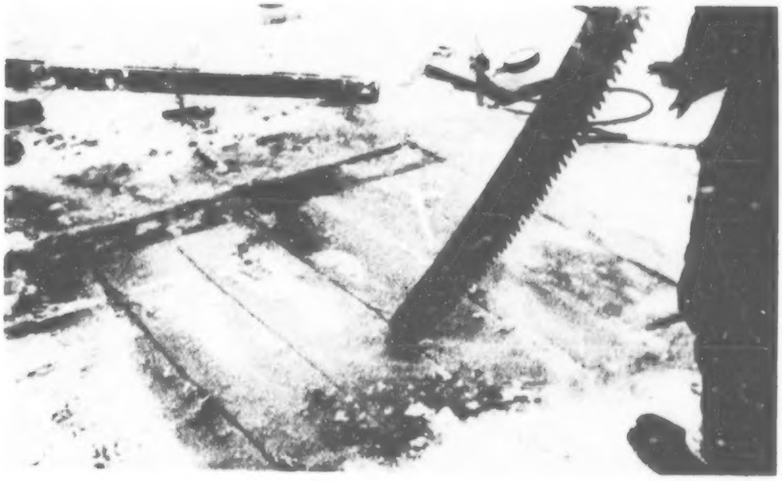

Figure 3: Final cutting of an ice beam prior to loading.

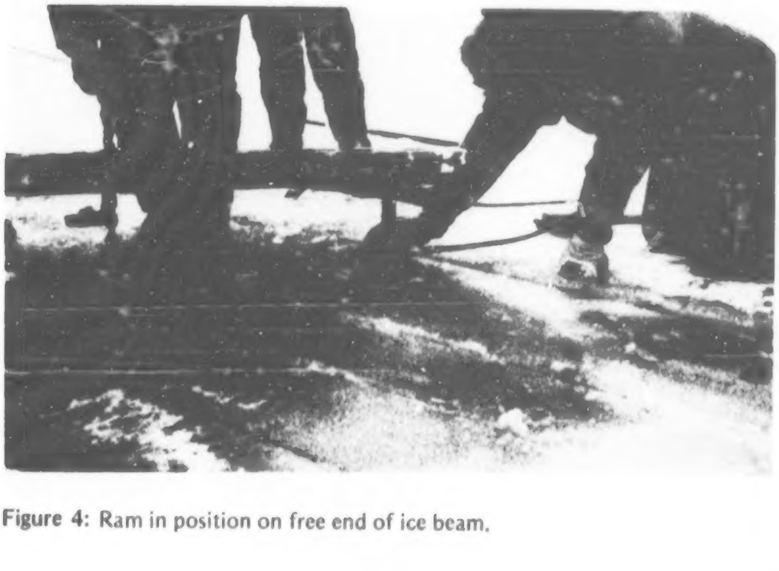

Figure 4: Ram in position on free end of ice beam.

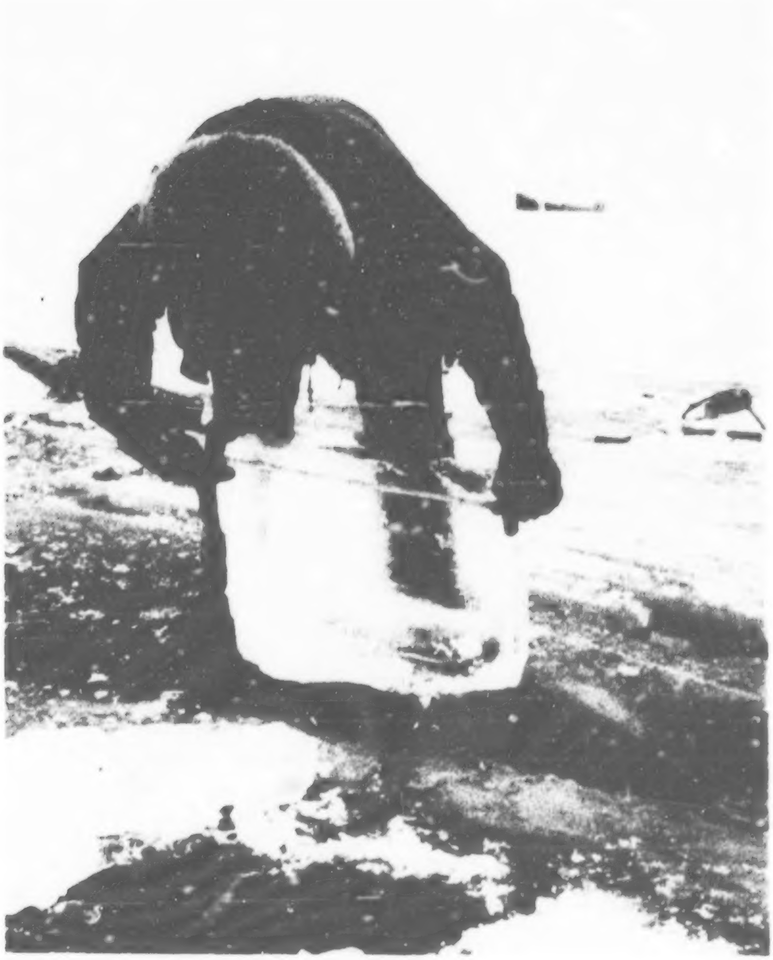

Figure 5: An ice beam removed from the ice sheet after failure.

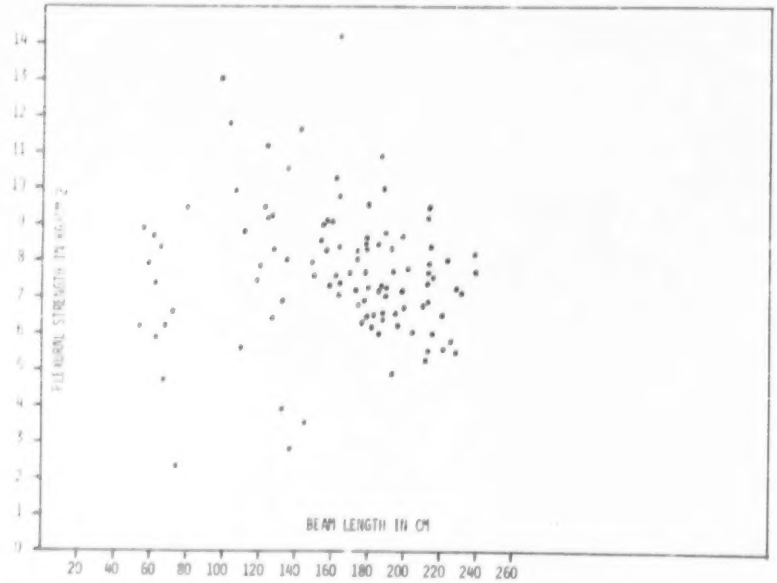

Figure 6: Flexural strength versus beam width.

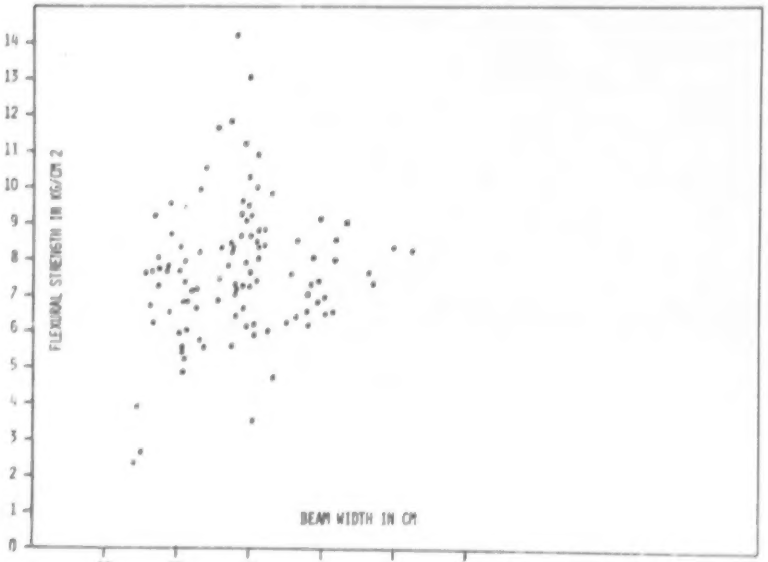

Figure 7: Flexural strength versus beam width.

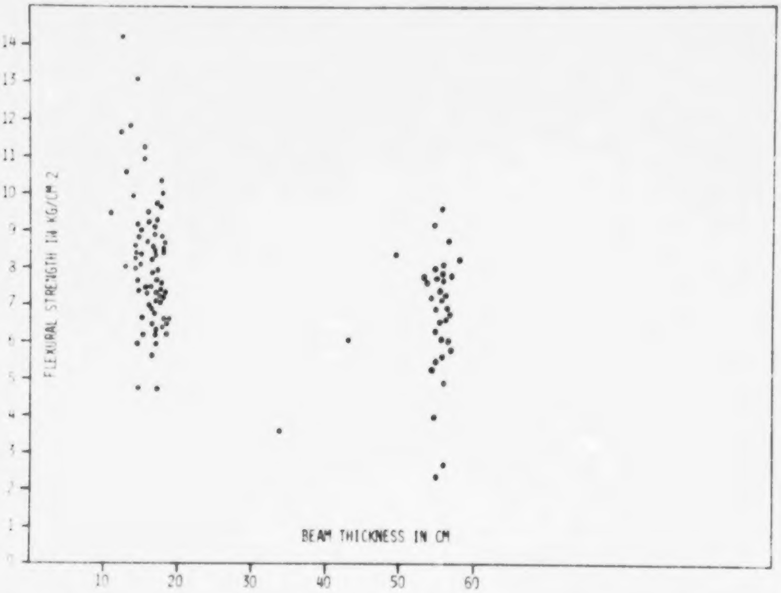

Figure 8: Flexural strength versus beam thickness.

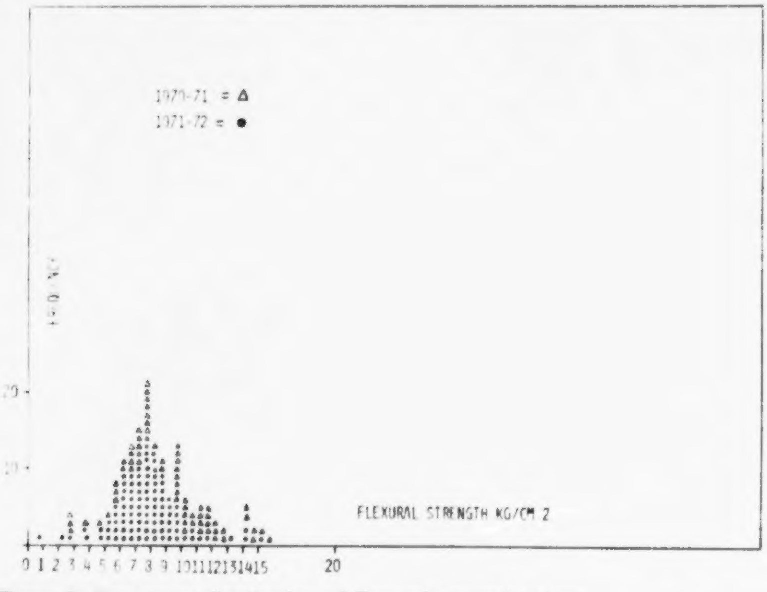

Figure 9: Frequency distribution of flexural strength values.

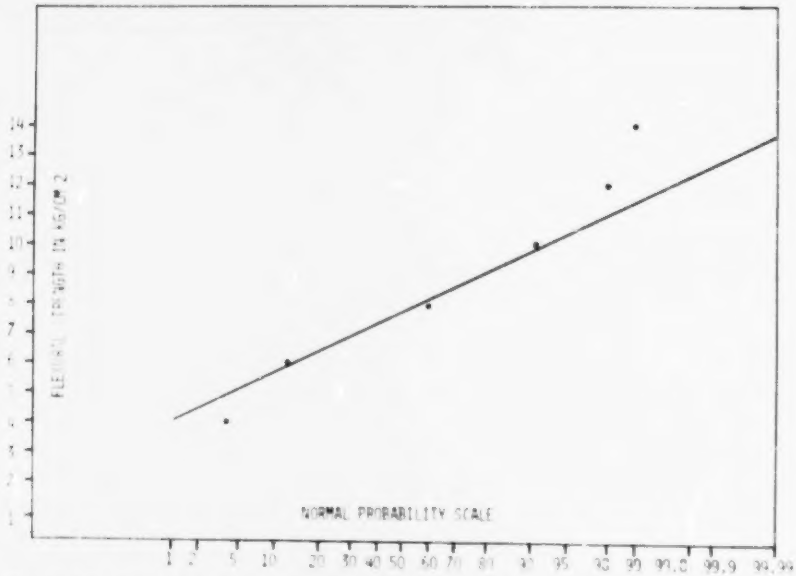

Figure 10: Graphic test of normality of the flexural strength values.

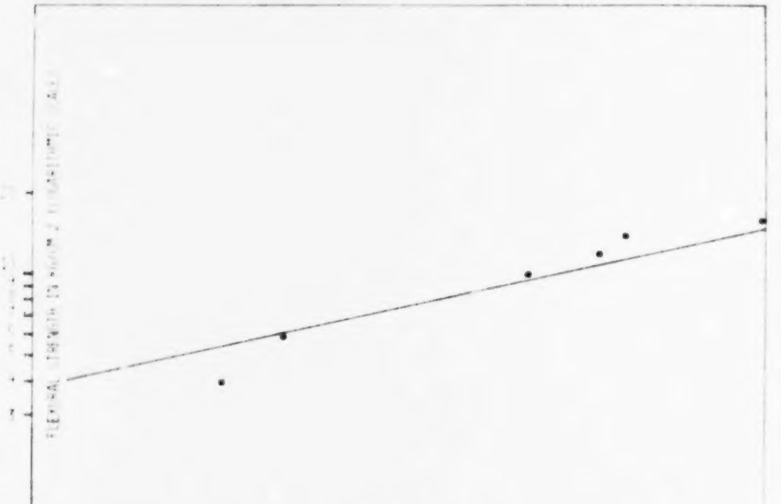

Figure 11: Graphic test of normality of flexural strength values with a logarithmic transformation.

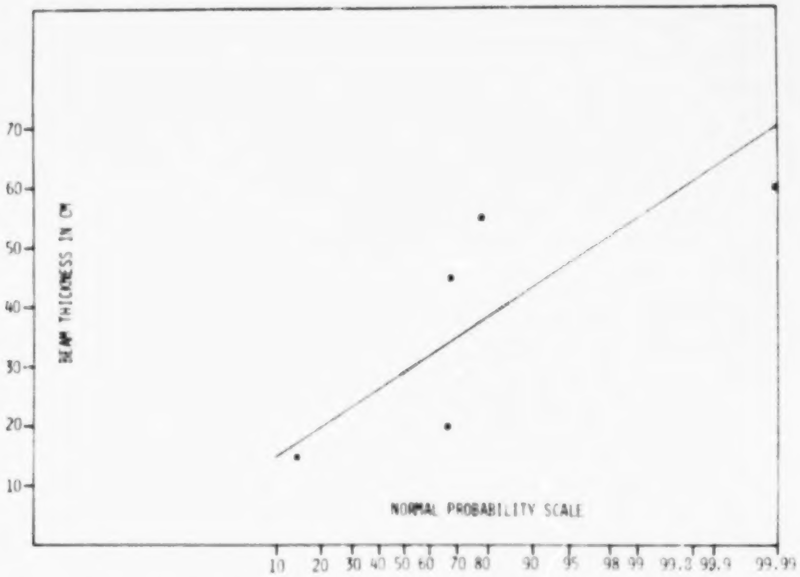

Figure 12: Graphic test of normality for ice beam thickness.

random selection is to insure that the investigator does not unknowingly bias his results. This was not done for any of the measurements made in this study. However, the practical considerations involved in obtaining samples in a field situation in a predetermined randomized way are often restricting. The restriction for this investigation is that inference could only be made to the sampled population. For example, the selection of a section of ice for the purpose of cutting a cantilever beam (to measure the flexural strength) is dependent on finding an area large enough, which is apparently strain free, to accommodate a beam. This is not easy. Of course, these problems do not obviate the requirement for a random sample in order to obtain meaningful statistical results. However, the effects and restrictions on the interpretation of the statistical results can often be assessed if the assumptions for a particular statistical technique are carefully examined.

The fundamental assumption that samples be selected at random was not assured in this study. The effects of this might be indicated by a lack of independence of the samples, heterogeneity of variances, or an abnormal distribution. These assumptions can be tested so that an objective evaluation can be made.

Regardless of the outcome of the statistical analysis, interpretation of the statistical results must apply only to the ice used as samples for the measurements made in this study. This defines a population which is called the available population of lake ice for a particular physical property of interest.

The assumptions tested and the techniques used are presented below.

Independence was tested using the Runs test (Sokal & Rohlf, 1969 and Siegel 1956).

Testing for normality was done using a graphic technique (normal probability graph paper) (Sokal & Rohlf, 1969).

Variance homogeneity was tested using F Max. (Sokal & Rohlf, 1969, David, 1952).

The detailed calculations for the above tests are contained in the previously-mentioned internal document in preparation. Some of the results are presented in a later part of this report.

The flexural strength values were analyzed using a single classification, Model II, analysis of variance (unequal sample sizes) technique (ANOVA). The technique is robust, so lack of normality is not a serious problem. Since the effects are random, estimating the magnitude of these random effects for any one beam set or the differences from beam set to beam set is futile. However, we can estimate the added variance component among beam sets, its magnitude and its percentage contribution to the total variation. The null hypothesis is that there is not an added variance component among sets of beams and that the two mean squares estimate the same variance.

Next the flexural strength was analyzed using the Wilcoxon two-sample test. This test was directed toward determining the equality of "location" for the Muskegon and Washington Island strength data. The "location" indicates if the two samples have the same distribution.

RESULTS

The results are summarized in the following discussion. Because this is a progress report, more detailed discussion must await the final publication.

Summary of Tests of the Assumption

The assumptions of independence, normality and variance homogeneity have been tested on the available data. The results are presented in Table 1.

Table 1: Summary of tests of assumptions

Source	Independent	Normal	Homoscedastic
Flexural strength			
Muskegon and Washington Island	Yes	No	Yes
Beam thickness			
Muskegon	Yes	No	No
Washington Island	Yes	No	No
Combined	Yes	No	No
Along-track thickness			
Washington Island	Yes	No	Yes

The result of the analysis of variance on the strength data is presented below.

ANOVA Table for flexural strength data

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Among sets of beams	(17-1)=16	193.98	$\frac{193.98}{16} = 12.12$	5.95*
Within sets of beams	(105-17)=88	179.33	$\frac{179.33}{88} = 2.037$	
Total	(105-1)=104			

$F_{(16,88)} = 5.95^{*}$

*Significant at alpha equals 0.05.

The level of significance was chosen as alpha equals 0.05. The conclusion was to reject the null hypothesis. There is an added variance component among sets of beams. It appears that there is more variation within sets of beams than between (among) sets of beams. It is very possible that this is the result of the interference of one beam with another during the field determination.

It would be helpful to know if the population of flexural strength values from Muskegon differed significantly from the Washington Island population. This can be done by testing the null hypothesis that the two samples come from populations having the same distribution. The computations for the Wilcoxon two-sample test are included in an internal report as are the ANOVA computations and will not be presented here. The value of the test statistic t_s is compared to tabled critical values (Table Q of Rohlf & Sokal 1969).

$t_s = 4.671$ for alpha equals 0.05 and infinite degrees of freedom (this is a one-tailed test). If the value of t_s exceeds the tabled value, the result is significant. $t_s = 4.671$ is greater than 1.645 thus there is a significant difference between the distribution of strength data for Muskegon and the distribution of strength data for Washington Island. They do not come from populations having the same distribution.

Considering the descriptive statistics, it appears that the distributions are overlapping with the Muskegon distribution's central "location" farther right (toward the larger strength values) than the Washington Island distribution (Table 2).

Table 2: Summary descriptive statistics

Source	Median	Mode	Range
Flexural strength	7.63 Kg/cm^2	None	2.35 to 14.2 Kg/cm^2
Muskegon	8.08 Kg/cm^2	7.07 Kg/cm^2	4.72 to 14.2 Kg/cm^2
Washington Island	6.85 Kg/cm^2	None	2.35 to 9.53 Kg/cm^2
Thickness			
Beam thickness			
Muskegon, Mich.	16.7 cm	17.4 cm	10.8 to 18.8 cm
Washington Isl., Wisc.	55.6 cm	56.5 cm	42 to 58.5 cm
Together	17.5 cm	17.4 cm	10.8 to 58.5 cm
Along-track thickness			
Washington Isl., Wisc.	52 cm	52 & 54 cm	49 to 69 cm

CONCLUSION

One conclusion at this stage of the investigation is that realization of the objectives is dependent on understanding some rather complex relationships. The inability to control or assess the contribution of various possible sources of variation is a major part of the complexity.

Considering the results of some of the tests of assumptions, it is apparent that certain summary type statistics (parametric) are inappropriate. It appears that the only appropriate descriptive statistics for summary are the median, mode, and range. These are not completely satisfactory because they do not provide for unique description as the mean and variance would if the variables were normally distributed.

More specific conclusions are listed below.

(1) The ice is not homogeneous with respect to the physical properties measured during this investigation.

(2) The individual data arrays are random samples of a random variable.

(3) Neither the strength data nor the thickness data are normally distributed.

(4) The strength data are homoscedastic.

(5) The variation of flexural strength is greater (54.7% of the total variation) within sets of beams than it is between sets of beams (43.3%).

(6) The flexural strength populations from Muskegon and Washington Island are overlapping. The measure of central tendency for each is displaced with respect to the other. The Washington Island distribution is overlapping and to the left (smaller strength values) of the Muskegon distribution of flexural strength values.

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National Science Foundation Funded Research in the Great Lakes

*Carl J. Lorenzen, Oceanography Section,
Division of Environmental Sciences,
National Science Foundation*

The National Science Foundation (NSF) was established by Congress in 1950 to promote the progress of science and to advance the national health, prosperity, and welfare. Under the principal provisions of the NSF Act of 1950, as amended through December 1, 1971 (42 U.S. Code 1861-1875), the Foundation was authorized and directed to initiate and support basic scientific research and programs to strengthen scientific research potential in the mathematical, physical, medical, biological, engineering, social, and other sciences through contracts or other arrangements; to initiate and support scientific research including applied research, at academic and other non-profit institutions, and at the direction of the President, support special applied research at other organizations. The Foundation, by terms of the Act, cannot itself operate any laboratories or pilot plants.

The Foundation does not have a research program limited to the Great Lakes but does support research activities in the marine and fresh water environments in addition to other research areas. The bulk of the funded basic research is conducted by U.S. academic institutions having been selected from unsolicited proposals by a peer evaluation procedure. Almost all of the research support is derived from the Oceanography Section, Division of Environmental Sciences. In addition to research support, the Foundation funds support research facilities, which in the case of Great Lakes research is the ship *R/V Inland Seas*. This support derives from the Office of Oceanographic Facilities and Support. During FY-71, the Foundation supported 13 research projects in the Great Lakes at a cost in excess of one-half million dollars. Including facilities, the total was approximately three quarters of a million dollars. The bulk of the research support was involved in International Field Year for the Great Lakes.

FUNDED GRANTS FOR PARTICIPATION IN IFYGL FISCAL YEAR 1972

1. Estoque, M. A., University of Miami, "Mesometeorological Effects on Lake Ontario," $52.3K
2. Panofsky, H. A., Pennsylvania State University, "Structure of Turbulence," $58.3K
3. Rao, D. B., University of Wisconsin-Milwaukee, "Numerical Studies on the Circulation and Storm Surges in Lake Ontario," $29.9K

4. Businger, J. A., University of Washington, "Participation in IFYGL," $60.8K
5. Telford, J. W., Desert Research Institute, "Application of the Buffalo Research System to Attain IFYGL Lake Meteorology Objectives," $79.3K
6. Piech, K. R., Calspan Corporation, "Optical Properties of Lake Ontario Waters," $36.5K
7. Lyons, W. A., University of Wisconsin-Milwaukee, "Satellite and Surface All-Sky Photography in Determining the Solar Insolation Climatology of Lake Ontario," $36.7K
8. Diment, W. H., University of Rochester, "Transport Processes Within the Rochester Embayment of Lake Ontario," $78.6K
9. Mozley, S. C., University of Michigan, "Pontoporeia Affinis and Other Benthos in Lake Ontario," $39K

The Smithsonian Role in Great Lakes Research

Dr. Richard Houbrick, Oceanography and
Limnology Program, Smithsonian Institution

The Smithsonian Institution's role in Great Lakes research activities is primarily centered on the biota of the Lakes. Biological samples serve as "time capsules" of ecological information which attain maximum usefulness when accompanied by other environmental measurements taken concurrently.

The Smithsonian Oceanographic Sorting Center (SOSC), operated by the Oceanography and Limnology Program of the Office of Environmental Sciences, performs analyses of biological oceanographic samples. The resulting data and sample components are managed so as to be available for multiple uses or uses specified by a project or program. Acting as a central processing laboratory, SOSC receives, sorts, records, curates and distributes biological collections in order to make them available to specialists for community analyses, environmental and biochemical studies, and taxonomic work. Information on SOSC holdings can be rapidly retrieved and subjected to analyses through the computer facilities of the SOSC Records Section. The biological data storage and retrieval system operates at all taxonomic levels of specimen identification and the use of data manipulation services are offered as an integral part of the specimen processing activities of SOSC.

The Oceanography and Limnology Program also plays an active role in environmental studies through its expertise in program management, sampling design, special research contracting, etc. The program attempts to standardize collection methodologies in order to establish valid between-station comparisons and a modeling capability for prediction and assessment purposes.

The Smithsonian, as the repository for national collections, can also serve in an advisory capacity to insure that standard procedures are used in the narcotization, fixation and preservation of biological specimens.

Summary of Atomic Energy Commission Supported Research and Programs

George W. Saunders, Division of Biomedical and Environmental Research, Atomic Energy Commission

The Atomic Energy Commission (AEC) was established in 1946 (P.L. 585) to succeed the Manhattan Engineer District of the U.S. Army Corps of Engineers as the agency responsible for the atomic energy program. The program was expanded by the Atomic Energy Act of 1954 to permit and stimulate private endeavor and international cooperation in the development and use of atomic energy for peaceful purposes. The national policy and broad objectives of the AEC are summarized in the law as follows:

(a) the development, use, and control of atomic energy shall be directed so as to make the maximum contribution to the general welfare, subject at all times to the paramount objectives of making the maximum contribution to the common defense and security; and

(b) the development, use, and control of atomic energy shall be directed so as to promote world peace, improve the general welfare, increase the standard of living, and strengthen free competition in free enterprise.

On July 23, 1971, the U.S. Court of Appeals for the District of Columbia Circuit decided the consolidated cases of Calvert Cliffs Coordinating Committee, Inc., et al *v* U.S. Atomic Energy Commission et al. The court held that AEC regulations for implementing the National Environmental Policy Act of 1969 in licensing proceedings did not comply in several respects with the National Environmental Protection Act (NEPA). The decision further defined the AEC's expanded authority in the environmental area, which involves the direct responsibility for evaluating and assessing total environmental impact of major nuclear facilities, including thermal effects.

The AEC research program provides quantitative information on the consequences of nuclear operations for human health and the environment. This information is used to develop procedures intended to assess the risks associated with these operations, assure safety for those persons occupationally involved, and the public. The program also provides information in support of national security, achievement of adequate sources of energy, preservation of a clean environment, improvement in health care, and exploration of space.

A basic tenet of the research program is that the general properties of systems derived from analytical research at one location can be applied to predict events at different locations. In some cases more detailed information may be required at specific locations. Research performed on the Great Lakes falls under the broad objectives of the AEC program, recognizing that specific information may be required in this geographical region.

Approximately half the population of the United States lives within 50 miles of the sea coast or the Great Lakes. The complexities of the Coastal region will have important effects on the transport and fate of all effluents released in these highly populated areas. It is therefore easy to understand that the Great Lakes drainage system is a region that requires focus of efforts that would lead to proper management of this important national resource.

In 1967 over 1/6 of the total projected nuclear power generating capacity in the U.S. was planned on the premise that the Great Lakes would be used as a source of cooling water. It was then estimated that up to 50,000 MW (e) in generating capacity could be installed on the Great Lakes by the late 1980's.

In anticipation of the need to evaluate the impact of this industry on the Great Lakes the AEC initiated a research program in 1968 designed to develop base line information and evaluate potential direct local effects of thermal, radionuclide, and nutrient inputs to the Great Lakes.

A summary of the AEC research program on the Great Lakes, with number of projects and funding levels for fiscal years 71, 72, and 73, is presented in Table 1. The research is supported by the Division of Biomedical and Environmental Research and the Division of Reactor Development and Technology. The program is divided into four general categories. These categories are air-water energy exchange, thermal effects, fates of radionuclides, and eutrophication processes. There is a total of nine projects which are described in more detail below.

In 1969 a project titled "Micrometeorological Measurements over Lake Michigan" was initiated through a contract carried out by the Atmospheric Physics Section, Radiological and Environmental Research Division, Argonne National Laboratory. This study is intended to develop understanding of the mass-energy balance of the Great Lakes. Very few direct measurements of the turbulent transfer phenomena that control this energy balance have been made on large lakes. A site considered to be representative of conditions over the open waters of the southern basin of Lake Michigan has been selected for analysis. Measurements include momentum flux, sensible heat flux, and latent heat flux. The normal daily cycle of several components of the air-water exchange and occasional discontinuous changes in these mechanisms associated with abrupt changes in meteorological conditions are being examined. Description of the interrelationships of these mechanisms on a basis of cyclic

Table 1: AEC Research Program on the Great Lakes

Type Program	No. Projects	Funding Level 1971	 1972	 1973
Atmospheric transport	1	30,000	50,000	50,000
Thermal effects	5	417,817	557,750	639,000
Fates of radionuclides	2	265,236	280,240	372,000
Eutrophication	1	68,345	68,345	68,500
Total	9	781,398	956,335	1,129,500

and aperiodic short-term variations is intended to provide a capability for assessing any irreversible long-term changes which could result from unrestricted thermal pollution.

The Division of Reactor Development and Technology (RDT) initiated a comprehensive study of power plant siting on the Great Lakes, particularly Lake Michigan, in 1969. Emphasis is placed on thermal effects relative to siting. Field measurements at operating power plants and potential sites are being made in cooperation with state resource agencies, utilities, and environmental groups. State-of-the-art reports on various aspects of thermal effects are being prepared. Physical scale modeling and analytical modeling are being verified to develop those mathematical models most suitable for predicting the extent of thermal plumes in large lakes.

In 1971 RDT initiated a field program to study the physics of nearshore circulation in Lake Michigan in the vicinity of an operating power plant. The coherence and phase relationships of temperature and current data are being analyzed. Description of the nearshore current regime and its seasonal variation will be reported. This information will be used to predict thermal plume transport and dispersion in the Great Lakes. This project is closely coordinated with modeling efforts conducted at Argonne National Laboratory.

Another project closely associated with the above program was initiated in 1971 to describe the thermal field nearshore to an operating power plant and compare the chemistry and biology of this area with a similar area not subjected to thermal perturbation. The purpose of this project is to determine if differences occur that can be ascribed to thermal input. Details of survival of organisms passing through the cooling system are also being examined.

Another project in the thermal area is designed to determine the effects of pressure and temperature on phytoplankton, zooplankton, and larval fish passing through the cooling systems of several fossil and nuclear power plants on Great Lakes waters. An experimental system designed to simulate the dynamics of pressure and temperature in cooling systems will be used to examine the effects of a range of possible conditions on selected phytoplankton and zooplankton cultured from the Great Lakes.

In 1970 DBER contracted with ANL a study of thermal inputs to the Great Lakes. The ultimate objective of this research is to be able to predict the total impact of waste heat discharges in the Great Lakes. It is intended to develop this program stepwise as critical problem areas are identified. Initially the behavioral responses of fish to thermal discharges from nuclear power plants on Lake Michigan is being emphasized. Fish populations may migrate over long distances. Congregation of various fish species in and near thermal outfalls occurs during certain seasons. It is necessary to know what fraction of total fish population may actually aggregate in plumes and thus be potentially susceptible to elevated temperature effects or, in the case of plant shutdown during winter, to cold shock effects. Secondary impact of predation may occur on fishes whose individual motility and behavior is affected by thermal changes.

In winter, thermal discharges nearshore may be more dense than colder lake water. In this case a thermal plume may sink until it contacts the sediment surface. Whether such a thermal field could disrupt the normal life cycle of benthic organisms in this case is not known.

The design of this program should establish whether or not there are significant local effects before regional studies or more intensive site specific studies are initiated.

The Radiological and Environmental Research Division, ANL, initiated a radioecological program on the Great Lakes in 1969. The ultimate objective of this research is an understanding of the biogeochemical behavior and pathways to man of radionuclides and trace elements in the Great Lakes and the capability of predicting the transport and fate of artificial radionuclides introduced into the Great Lakes from any source. The initial work will determine the present distribution of radionuclides and trace elements in Lake Michigan water, sediments, and organisms believed to be important in cycling and in the pathways to man.

The distribution of trace elements, in particular, potentially toxic elements, is being determined in the vicinity of major tributaries to Lake Michigan, e.g., the Grand River, Michigan. These tributaries carry a heavy load of contaminants from various commercial sources. Not all of these trace elements would be derived from nuclear power generation. However, the plume of water entering Lake Michigan is easily identified, and results from these studies could be used for modelling the more local and less intensive releases that potentially might occur in plumes from power plants.

A baseline study of plutonium and americium concentration along fresh-water food chains in Lake Ontario is being conducted in cooperation with Woods Hole Oceanographic Institute and Lawrence Livermore Laboratory. Present concentrations are derived from radioactive fallout. Increased use of plutonium will occur with the development of breeder reactors for power generation. Information derived from these studies will be used to predict the ultimate distribution of these radionuclides in the Great Lakes and to anticipate potential impacts and proper location of generating plants on the Great Lakes.

One study of the effects of excessive inputs of nutrients on phytoplankton is under contract with the Great Lakes Research Division, The University of Michigan. The intent is to understand the causes, mechanisms, and environmental relationships of processes associated with eutrophication and to discern possible changes in phytoplankton production, growth, abundance and species composition. This project is being conducted at the Grand River plume and therefore supplements other studies being conducted in this area. The results of this program will be used to model the potentially less intensive impacts of nuclear power plants.

The Great Lakes are very large and cannot be examined in detail or with regard to every possible environmental impact. AEC-supported research on the Great Lakes is therefore designed to discern whether or not certain potentially adverse impacts from a developing nuclear power industry are or could be significant in causing major changes in the Great Lakes and utilization of this natural resource. The present research projects being conducted on the Great Lakes are complementary and should produce a maximum information return for the dollar investment. Future research direction, whether it is expanded toward broader regional analyses or more detailed site specific analyses, will depend on conclusions derived from this presently ongoing research.

The Department of Agriculture and its Cooperators—How They Relate to the Great Lakes Basin

Dr. David J. Ward, Department of Science and Education, Department of Agriculture

ABSTRACT

The Department of Agriculture and cooperating institutions have responsibilities for research on the prevention and control of agricultural and forestry sources of water pollution. A wide variety of research projects relate to optimum use of agricultural chemicals with minimal adverse environmental impact, to environmentally safe animal and food processing, waste management, and to soil and water conservation for minimal soil erosion and sediment development. Also, research continues on principles of land use potential of specific sites as related to environmental impact. Much of this research has direct application to water pollution from non-agricultural and forestry sources, for example, sewage disposal on land, erosion and sewage management in resort planning, and in general land development.

* * *

Large bodies of water such as the Great Lakes are not a major focus of the Department of Agriculture. But land is—all kinds of land, land and the things that live and grow there, the physical and biological processes that operate there—land and the water that falls, permeates, flows, erodes, and aggregates there.

The Department is a grass roots organization. In the Great Lakes Basin, as in all other parts of the U.S., its programs are accomplished with and for many kinds of local cooperators. I emphasize "with." For it is with individual landowners or operators, with land grant universities and their experiment stations, forestry schools, and extension services; with soil conservation and other kinds of natural resources districts; with state departments of governments; and with local governments, commissions, councils and so on, that most USDA programs for understanding, managing, and improving natural resources are conducted.

Key environment-related USDA functions performed by nine agencies[1] are those of research, extension education, regulation, technical assistance, financial assistance, and in the case of national forests, directly managing natural resources.

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[1] Animal and Plant Health Inspection Service (APHIS), Agricultural Research Service (ARS), Agricultural Stabilization and Conservation Services (ASCS), Cooperative State Research Service (CSRS), Economic Research Service (ERS), Extension Service (ES), Farmers Home Administration (FHA), Forest Service (FS), Soil Conservation Service (SCS).

What about the lands and attendant waters of the Great Lakes Basin? How do the programs of USDA and its cooperators relate to these lands? A necessary first point to make is that in addition to activities undertaken within the Great Lakes Basin, there are research activities the findings and benefits of which are applicable to the Great Lakes area even though the work is conducted elsewhere. A second point is that the competencies of agriculturalists for characterizing and managing soils, topographies, and landscapes in terms of their potential utility and fragility, particularly from an erosion standpoint, are usually applicable to urban and industrial settings as well as to agricultural ones.

Selected activities of the nine USDA agencies relating to environmental considerations in the Great Lakes Basin are listed below:

APHIS	(regulation) Control of pests Regulation of animal assembly areas and meat and poultry processing
ARS	(research) Management of soil and vegetation Understanding of hydrologic systems Management of agricultural wastes, including disposal of all kinds of organic wastes on land Controlling pests Development of new and improved technology for processing agricultural commodities Rehabilitation of lands
ASCS	(financial assistance) Assistance in soil conservation, pollution control, and environmental improvement practices, including cost-sharing for wildlife habitat development
CSRS	(Research–formula and special grants to state agricultural (Experiment stations, forestry schools, and colleges of 1890) Same scope as ARS, ERS and FS
ERS	(research–costs, benefits, institutional arrangements) Rural waste management Pest control Rural recreation Water management
ES	(extension education) Rural waste management Control of pests
FHA	(financial assistance) Developmental costs of farm operators Water and sewer and waste disposal systems for communities and other forms of local government Developmental costs of businesses in rural America

FS (research, technical assistance, management of National Forests)
- Management of timber and associated vegetation, wildlife, grasslands, and other natural areas
- Water production
- Recreation in rural areas
- Urban forestry
- Waste disposal on land
- New and improved wood and wood products processing technology
- Understanding of hydrologic systems
- Control of pests
- Wildlife habitat
- Rehabilitating lands

SCS (technical assistance)
- Management of soil and vegetation
- Soil interpretation
- Control and impoundment of water
- Wildlife habitat
- Rehabilitation of lands

Application of agricultural technology involves potentials for environmental degradation as well as for environmental protection and improvement. It is USDA policy to direct its programs toward managing the environment for the widest range of beneficial uses without environmental degradation or risk to health or safety or other undesirable consequences.

In the Great Lakes Basin, as in the rest of the country, forests, wildlands, wetlands, natural areas, farms, ranches, and rural communities must continue to provide water, wildlife habitat, recreation areas, energy sources, transportation routes, diverse employment opportunities, space for living with amenities and services, and scenic beauty while producing food, fiber, and forest products as needed.

Great Lakes Alternative Futures and Impact on Research

Frederick O. Rouse, Chairman, Great Lakes Basin Commission

As President Nixon stated in his 1972 environmental message, "The environmental awakening is stimulating a revolution in values, a commitment to responsible partnership with nature." Over the past several years there has been much legislation to help meet growing demands for environmental quality. The Water Resources Planning Act of 1965, Public Law 89-80, enabled state governments concerned with water and related land resource problems to recommend the establishment of organizations which would coordinate their efforts with those of the federal government to establish an environmental ethic. The Great Lakes Basin Commission is one of seven such organizations established across the nation. It is charged by law with coordinating planning for water and related land resources throughout the Great Lakes Basin and fostering studies necessary to this activity and to recommend long-range priorities for the collection and analysis of basic data, investigation, and construction of projects.

The Great Lakes system is recognized as one of the United States' greatest natural resources, used by citizens as a source of water, food, economic advantage, recreation, transportation, and general aesthetic pleasure. The Great Lakes Basin reflects national trends toward urban growth and a diminishing agricultural population, areas of both affluence and economic deprivation, and unmarred natural areas and sections scarred by careless use and development. It has become obvious that economic growth is desirable not as an end in itself but for the achievement of specific goals. Our relationship must change from exploitation to support of the environment.

The Basin Commission's approach to planning is consistent with the Federal Water Pollution Control Act Amendments of 1972 which state:

(1) Discharge of pollutants to the navigable waters shall be eliminated by 1985.

(2) Where attainable, an interim goal of water quality providing for protection and propagation of shell fish and wildlife and recreation in and on water shall be achieved by 1983.

(3) The discharge of toxic pollutants in toxic amounts shall be prohibited.

(4) Federal financial assistance shall be provided to construct publicly owned waste treatment works.

(5) Areawide waste treatment management planning processes shall be developed and implemented to assure adequate control of sources of pollutants in each state.

(6) A major research and demonstration effort shall be made to develop technology necessary to eliminate discharge of pollutants into navigable waters and waters of the contiguous zone.

If federally-funded or managed research is to support these basic goals, it must be programmed within the projected needs of the nation and the Basin.

The Great Lakes Basin Commission is engaged in actively planning the steps which will reduce the likelihood of increased and continued water resource misuse. Against the background of quality standards of water resources for the Great Lakes Basin as set by Congress in the Federal Water Pollution Control Act and its Amendments of 1972 and the Executive Water Quality Agreement between Canada and the United States, the Basin Commission is rapidly drawing to a close the first step of its planning duties, that of generating a framework on which to base the legally assigned "comprehensive. coordinated, joint plan" (CCJP).

It is desirable to view population and economic development trends and their probable impacts on areas and topics for research which will enhance plan formulation.

Great Lakes Basin population and employment growth have traditionally paralleled national growth trends since 1929. Population in the Basin in 1970 reached 29,332,000, a figure which represented 14.4 percent of the nation's total population. Coincidently, employment of 11,302,000 in the Basin also represented 14.4 percent of the nation's total employment. Even so, the Basin occupies only 4 percent of the nation's land. Figures 1 and 2 illustrate the Basin's mirror of national trends in population and employment. These figures are projections that the Office of Business Economics and the Economics Research Service consider to be likely growth patterns for the Basin up to the year 2020. Population in the Basin will then be slightly lower in comparison to the previous rate of 14.4 percent. However, the labor force is expected to increase from 37 to 40 percent of the population as job opportunities increase more than the population rate. This will also be reflected in an increase in total personal income.

As required under U.S. Water Resources Council (October, 1967), the Great Lakes Basin Framework Study will project for years 1980, 2000, and 2020 land use patterns to the extent necessary to appraise in general terms the needs for water resource development, and the effects of land use on projected water resources availability, management, and development.

Traditionally, long-range planning studies (50-year periods) have relied upon the past as a basis to predict the future. Projections are necessarily based on an extension of past relationships believed to have future relevance for the measure being projected. The selection of past relationships to be extended and the methodology for their extensions are based on assumptions. It is, therefore, impossible for these projections to become predictions of future events, unless all assumptions and assumed conditions become actualities.

The Great Lakes urban region is undergoing a process of megalopolitan formation, a fact which the Basin Commission has responsibility to project in a selection of alternative futures, which may significantly deviate from its past performance record. To allow for unforeseeable conditions that would

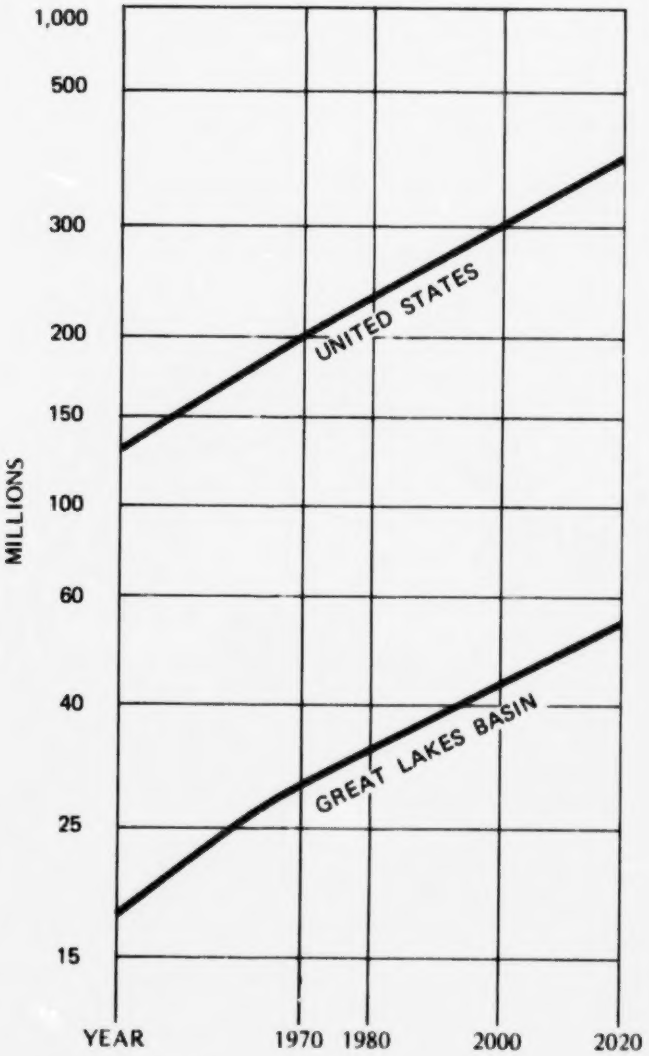

Figure 1: Projected population.

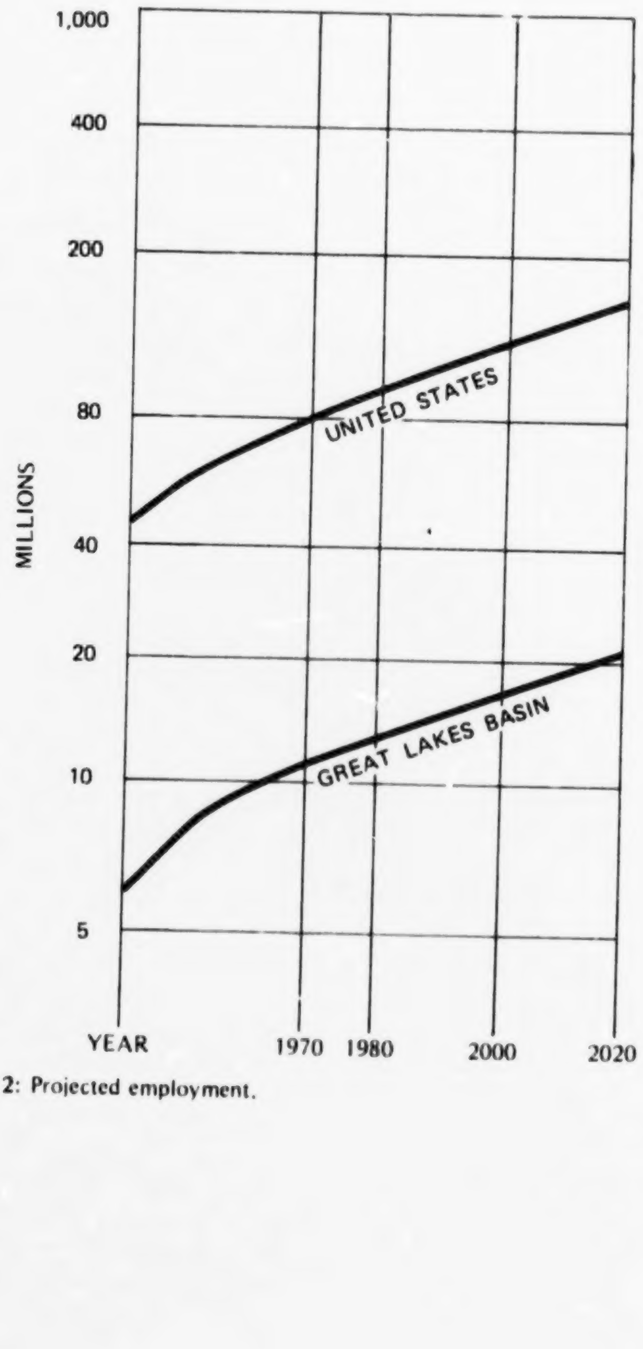

Figure 2: Projected employment.

influence the validity of projections, the Great Lakes Basin Framework Study uses alternative futures as dynamic planning tools for projecting new growth directions in the Basin.

GREAT LAKES BASIN FRAMEWORK STUDY PROJECTIONS USED TO ESTABLISH ALTERNATIVE FUTURES

A range of three levels of population and regional economic activity was projected for the next 50 years in the Great Lakes Region. These projection levels used:

(1) the Great Lakes regional disaggregation in 1968 of the Office of Business Economics and the Economic Research Service (OBERS) national economic and demographic projections, assumed to reflect normal growth conditions

(2) the accelerated and limited growth projections resulting from a GLBC computer program, Alternative Demand, Supply, and Need (ADSUN), utilizing the OBERS series of "Effects of Alternative Assumptions on Projections of Gross National Product for the years 1980, 2000, 2020," prepared in late 1971

The projection levels are normal, accelerated, and limited growth rates.

The normal level of development is associated with objectives of national economic development and based on projections of historical population and resource demands trend. It represents a middle-ground approach to growth.

The accelerated growth rate is associated with maximum possible population and per capita demand increases. It assumes regional development is of primary importance and will generate increasing demands for energy, goods, and services relative to national economic development in order to promote a higher regional percentage of Gross National Product. This growth projects an increased willingness to exploit natural resources and relegates cultural, aesthetic, and environmental factors to positions of secondary importance. Emphasis on structural alternatives for resource management is implied.

The limited growth rate is characterized by a minimum population growth and minimization of per capita demands for resources. Its basis is that preservation and restoration of the natural environment are of primary importance. Heavy emphasis on the natural, cultural, and aesthetic aspects of resource management is implied. Population is projected on a base approaching zero population growth, and unit demands for energy, goods, and services relative to the normal growth level are substantially reduced and assumed to level off over the projection period.

There are two key factors in the interpretation of regional projections for the Great Lakes. First, all projections made in the study were from a national base, disaggregated to the Great Lakes using judgements of the Great Lakes share of a national economic and/or demographic parameter. No new assumptions concerning national and regional economic structure were made for accelerated and limited growth frameworks. Second, there are no confidence limits placed upon any of the projected growth levels. Judgments have been made to shift the regional competitiveness of the Great Lakes to represent accelerated and limited growth levels. The study does not evaluate where relative gains and losses would take place within other regions of the nation. No subregional shifts in share of projections are assumed within the Great Lakes region itself.

The general assumptions made for projections of each future growth condition have been identified for factors affecting population, economy, and resource consumption. These are assumed to be high, medium, and low for accelerated, normal, and limited conditions, respectively. This indicated, in the broadest sense, the influence of each alternative projection upon resource demand.

The Commission on Population Growth and the American Future made the following generalizations regarding the consequences of population on the economy:

(1) Major economic changes are indicated regardless of future changes in population growth rates.

(2) From an economic point of view, population stabilization would bring benefits, especially if the United States develops policies to take advantage of the opportunities for social and economic improvement that slower population growth would provide.

The Great Lakes Basin Framework Study through its alternative frameworks provides the opportunity for the residents and legislators of the Basin to make informed decisions.

POPULATION

Over 29 million people resided in the Great Lakes region in 1970. More than 85 percent of that total lived within 50 miles of the shores of Lakes Erie and Michigan. Normal growth projections pose a gradual decline in the regional share of the national population levels to just over 13 percent, as opposed to the previously mentioned 14.4 percent. This amounts to over 53 million people by 2020. Accelerating growth projected for the nation and the region shows shifts of population from other parts of the country to the Great Lakes Basin to total more than 17 percent of the national total, or 85 million persons by 2020. Given implicit or explicit growth policies to limit national population to near zero population growth levels, and to curtail population pressures on regional natural resources in the Great Lakes, the limited growth level reaches 37 million persons, with the region accounting for less than 11 percent of the national population in 2020. With the exception of the Lake Superior region, all areas within the Great Lakes are projected to gain in population through the next 50 years.

EMPLOYMENT AND INCOME

In 1970 the Great Lakes region's work force was approximately 12 million persons or 15 percent of the national work force. The region's share of the national employment by 2020 is assumed to increase to over 17 percent, decrease to 13 percent, and to 11 percent under conditions of accelerated, normal, and limited growth, respectively.

In the period 1940 to 1960, the Great Lakes region maintained about 18 percent of the nation's total personal income while averaging over 20 percent higher per capita income than national levels. The heavy concentration of industrial activity in the region played a major role in income performance, and in 1970 total personal income in the region neared $114 billion.

Projections of personal and per capita income for normal growth conditions are consistent with trends for population and employment for the Basin and with respect to the nation. Accelerated growth assumptions project the region at 18 percent of the nation's personal income by 2020, while limited growth conditions decline to near 12 percent of the national income levels. Although variable over the Great Lakes area, per capita income values in 1970 range between $3,000 and $4,000 per year, Lakes Michigan and Erie highest.

ECONOMIC PRODUCTION

Projections of agricultural activity, manufacturing, forest, and mineral production are particularly significant for future planning in that they depend upon the utilization of basic natural resources in the Great Lakes Basin. Figures 3, 4, and 5 reflect earnings in manufacturing, mining, and agriculture for the alternative time frames and growth frameworks, respectively.

The Great Lakes Basin Commission has presented two variables to the normal growth trend, and each or a combination of alternatives is a feasible future. Should people decide to control their economic growth to salvage their environment? Is it necessary to have one without the other? "If the sole objective were pollution abatement or the conservation of natural resources, a

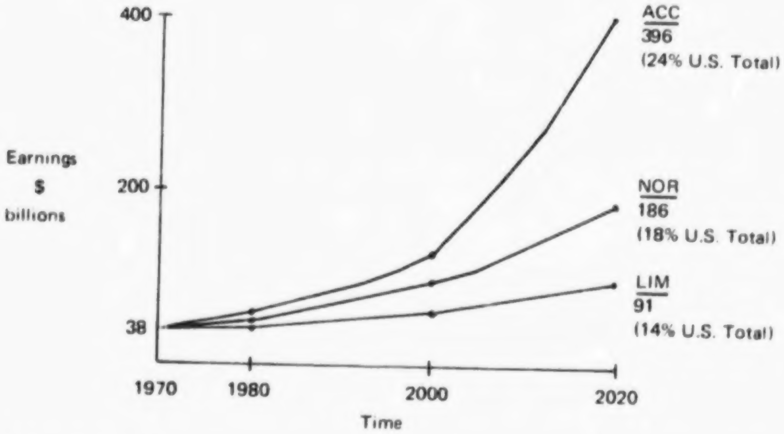

Figure 3: Projected total earnings in manufacturing Great Lakes Region (1967).

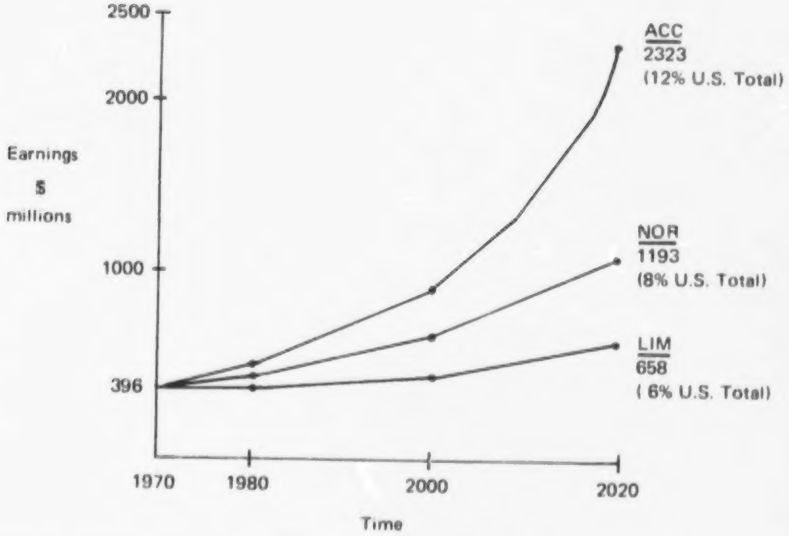

Figure 4: Projected earnings in mining Great Lakes Region (1967).

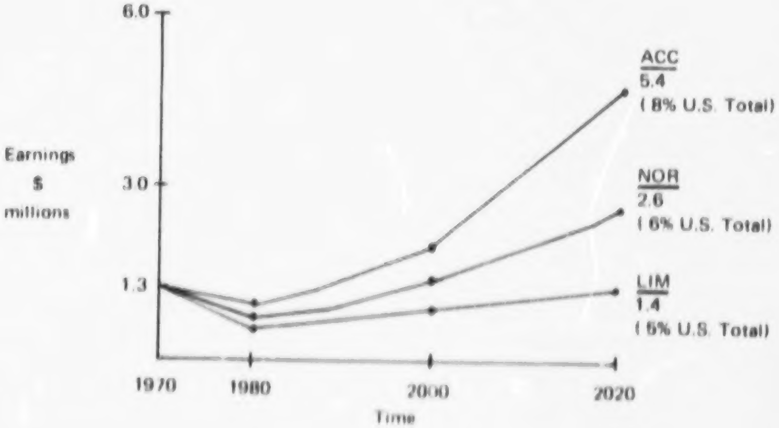

Figure 5: Projected earnings in agriculture, Great Lakes Region (1967).

reasonable argument could be made for reducing Gross National Product to the lowest levels possible," according to the 1970 Annual Report of the Council on Environmental Quality.

In 1969 the President established the National Goals Research Staff to identify for decision-makers the direction in which events were moving. The National Goals Research Staff reported that full employment is a goal as specified by law and that other goals, although not mandated, are essential: adequate rate of growth, reasonable stability of general level of prices, and a satisfactory balance of payments. To pay for economic growth through irreversible damage to the environment is not a satisfactory balance of payment. The search for "quality of life" and the appeal for reordering of national priorities reflect the desire of a society that wishes to enjoy what it produces to live harmoniously with the physical environment.

Water and related land requirements for normal growth are extensively documented in the 23 functional appendixes prepared for the Great Lakes Basin Framework Study. The subject areas discussed are:

- Alternative Frameworks
- Surface Water Hydrology
- Geology and Groundwater
- Limnology of Lakes and Embayments
- Mineral Resources
- Water Supply—Municipal, Industrial, and Rural
- Water Quality
- Fish
- Navigation—Commercial and Recreational Boating
- Power
- Levels and Flows
- Shore Use and Erosion
- Land Use and Management
- Flood Plains
- Irrigation
- Drainage
- Wildlife
- Erosion and Sedimentation
- Economic and Demographic Studies
- Laws, Policies, and Institutional Arrangements
  - Federal
  - State
- Outdoor Recreation
- Aesthetic and Cultural Resources
- Health Aspects

A series of 15 public meetings on alternative frameworks held at cities throughout the Great Lakes Basin from October through December 1972 served to educate both public and planners, the public concerning possible futures, and the planners concerning public needs and demands toward choosing a framework. In order to meet the public's needs, Great Lakes Basin Commission planners must formulate workable, flexible plans which will accommodate the changing economy, population, and public values systems. They must have available appropriate updated data.

Unfortunately, there are broad gaps in some data. Research is needed at both unidisciplinary and interdisciplinary levels. No matter which alternative framework comes closest to occurring, the need for research will remain. If the public chooses a limited growth pattern, research will be needed to reverse destructive environmental trends, just as it will be needed to support a normal growth pattern. An accelerated framework future will require research to develop better methods of pollution control and resource reuse. New energy sources will be needed to support the other processes.

If people develop a pattern of limited growth through education and restructuring of their goals, they will use resources at minimum rates and promote environmental quality rather than rapid economic growth. This will mean that people will have to use the resources they allocate to economic growth and production (even limited growth) to the fullest capacity. Less money will be available for spending, and the ability to undertake research in new areas of technology will be of prime importance. There is a need for better understanding of the relationships between and among water, economic development, and the environment, and new techniques for the management of water.

Major areas of needed research are:

(1) ecological, environmental, and socio-economic impacts of water resources project development and management strategies

(2) economic, social, and environmental costs and benefits of various levels of wastewater treatment, including the no-discharge alternative

(3) effects on water quality of nonpoint sources of pollution, including investigations of alternative means of control and study of urban storm water control on the quality of the lake water body

(4) means of more efficient water use and extending the utility of existing supplies

(5) relationships between energy production and water use and the effects of heat and consumptive use on local water resources

(6) new and developing technologies in water, including such things as desalting, weather modification, wastewater reuse, and geothermal resources

The Great Lakes Basin Commission is in the process of compiling and assembling a list of more specific research needs than mentioned above. A preliminary list follows. It should be remembered that the somewhat categorized list is only a first response to queries developed by member agencies of the Great Lakes Basin Commission. The list is not ranked in priority. Even so, it is none too soon to start filling the implied data gaps.

When the Great Lakes Basin Framework Study is published in 1974, a more comprehensive list will be included. While individual items will vary, research will continue to be required for the Great Lakes Basin as long as man lives in the Great Lakes Region.

RESEARCH NEEDED FOR GREAT LAKES BASIN: CATEGORIZED PRELIMINARY LISTING

Climate and Meteorology

(1) *Weather modification*, in intense snowfall areas downwind from Lakes (e.g., Indiana shore, Grand Rapids, Syracuse, and Buffalo regions)
(2) *Microclimate*, to determine increased incidence of plant diseases due to changed microclimate and possible economic significance (e.g., under irrigation and near windbreaks)
(3) *Air drainage and frost control*, to evaluate the effects of land contours, water bodies, and vegetation on frost sites (application: toward generating an index of fruit growing sites)
(4) *Air currents*, methods of measuring, and the influences of natural and manmade physical factors on them
(5) *Temperature*, to determine influences of air and soil temperatures on sap flow and budding of fruit trees

Limnology of Lakes and Embayments

(1) *Air-water interactions*
(2) *Definition* of common and disparate characteristics, factors, and functions of Great Lakes embayments vs estuaries
(3) *Chemical damage to Great Lakes*, to evaluate damage
(4) *Sediment-water interaction*, nature and extent of
(5) *Biotic assimilation* analysis
(6) *Biological magnification* analysis
(7) *Synergism of potentially harmful chemicals*
(8) *Toxic limits of Lake biota*
(9) *Bacteria-fungi nutrient cycling*
(10) *Organisms*, occurrence and metabolisms of (sources of undesirable drinking water)
(11) *Total ecosystem of Great Lakes*
(12) *Northern Lake Michigan and Lake Superior basin sediment analysis* (textural and mineralogical) to complete distribution patterns
(13) *Dye-tracing of sediment*

Mineral Resources

(1) *Technological and innovative applications to minerals problems*, degree of

Water Supply

(1) *Chemical trace, toxic material, heavy metal concentrations*, evaluation of physiologic impact on humans due to long-term ingestion
(2) *Water treatment processes to remove viruses*, trace metals, toxic chemicals and materials

(3) *Total dissolved solids*, measures for control of buildup in Great Lakes
(4) *Processes to reduce water use in industry*, applications of reuse
(5) *Processes and applications for reduction in municipal water use*
(6) *Socio-economic and ecologic impact analyses* of alternative future projections described in Great Lakes Basin Framework Study

Water Quality

(1) *Radioactive material*, measures to control discharges into Great Lakes systems
(2) *Tolerances and desirable maximum limits* in Great Lakes waters of:
    Ammonia
    Arsenic
    Barium
    Cadmium
    Chloride
    Chromium
    Copper
    Cyanide
    Fluoride
    Lead
    Mercury
    Nickel
    Oil
    Organic chemicals
    Phenols
    Selenium
    Sulphate
    Zinc
(3) *Contaminant removal by microorganisms*, including occurrence in ground water, and alternative means of contaminant removal

Fish

(1) *Fish populations and communities*, mathematical models for evaluating alternative management systems
(2) *Fishery impact evaluation*, assessment of ecological change probabilities under various environmental circumstances
(3) *Pesticide mineral and waste discharge tolerances* on fish and habitats
(4) *Stability in species and pre-predator relationships*, methods of establishing
(5) *Reaction to exploitation and/or predation* of various species
(6) *Individualized biological characteristics of species*, definition and analysis of, as related to specific influences
(7) *Toxins for rough fish control*, development of

Pond Management

(1) Acceptable weed control methods

Power

(1) *Power generation*, new methods
(2) *Power plant impact on environment*, evaluation of and methods of reduction
(3) *Treatment and disposal of gaseous, liquid and solid wastes* of fossil and nuclear power plants
(4) *Water effluent mixing methods* and criteria for heat rejection
(5) *Beneficial use of waste heat* for space heating

(6) *Flue gas desulfurization* methods
(7) *Coal gasification* methods
(8) *Physical and biological changes in water receiving thermal input*, assessment

Lake Levels and Flows

(1) *Evaporation from each Great Lake*, reliable method of estimating annual and monthly
(2) *Behavior of ice in Lakes and rivers* under changing flow conditions, particularly outlet of Lake Huron
(3) *Impact of Niagara Falls on water characteristics* of Lake Ontario
(4) *Vertical and horizontal water diffusion* factors in Great Lakes

Land Use

(1) *Causes and effects of corrosive soils* on water control structures
(2) *Untillable land*, methods of seeding rock or stump covered land
(3) *Seeding without tillage* following tree removal or aerial spraying, methods
(4) *New uses of low-quality timber*

Erosion

(1) *Methods of controlling erosion*
(2) *Methods of establishing vegetation*
(3) *Beach protection, shore erosion*, methods of control without adverse effects on littoral drift

Instrumentation, Techniques, Standards, Regulations and Vocabularies Needed

In addition to research, there are needs for support instrumentation, vocabulary, and techniques:

(1) *Terms and definitions for lake ice*, a universal set
(2) *Instrumentation to measure wind stresses* and turbulent atmosphere
(3) *Improved culturing techniques* for obscure groups of bacteria and fungi
(4) *Sediment grain size standard* measurement method
(5) *Great Lakes inflow-outflow forecasting*, methods for hydrologic resource planning, annually and monthly
(6) *Underground power transmission systems*, development
(7) *Plastic drain tube*, locator methods to determine depths and grades underground
(8) *Pest control products*, legal and regulatory measures to control input to water

The Council on Environmental Quality

Colonel James L. Trayers, Jr., Council on Environmental Quality

The Council on Environmental Quality (CEQ) was authorized under the National Environmental Policy Act of 1969 which was signed into law on January 1, 1970. Among the functions performed by the Council are development and recommendation of national policies which promote environmental quality; coordination of environmental programs among federal agencies; review of environmental impact statements; and, the preparation of an annual report.

The Council consists of three members appointed by the President and is served by a staff of about 30 professionals. The staff consists of the general counsel, staff director, secretary to the council, international affairs advisor, scientific advisor, the federal impact evaluation staff and three program development staffs.

The federal impact evaluation staff is organized along federal agency lines and its function is to receive the environmental impact statements submitted by the federal agencies. To date the federal impact evaluation staff has received a total 3,553 draft and final impact statements. Although the National Environmental Policy Act requires that each environmental impact statement be made available to the Council there is nothing in the Act which specifies what the Council is to do with the statements once it has received them. There are, however, two constraints which help define the Council's role in the impact statement process.

First, the National Environmental Policy Act does not transfer to the Council the responsibility to make any of the decisions that are reported in environmental impact statements. That responsibility remains with the federal officials who administer the programs and who prepare environmental impact statements. In short, the Council has no legal veto power over agency proposals.

Second, the National Environmental Policy Act establishes the Council in the Executive Office of the President as a small policymaking and coordinating group. With a total staff of less than 60, the Council cannot make a thorough study, even for advisory purposes, of every impact statement filed with it.

Within these limitations, what role does the Council play in the impact statement process?

First, the Council is charged with issuing guidelines to federal agencies for implementing the National Environmental Policy Act. Through this guideline mechanism, through assistance to agencies in preparing their own internal procedures for implementing the National Environmental Policy Act, and through continuing consultation with agencies on their performance, the Council assists the agencies to incorporate consideration of environmental factors into the early stages of the decisionmaking process.

Second, the Council uses the impact statement process to identify recurring substantive problems that point to a need for general reform of a federal program through administrative action, Presidential order, or legislation.

Third, the environmental impact statement process alerts the Council to projects whose environmental effects are significant and which warrant careful review. After reviewing the environmental impact statement the Council may advise the initiating agency or the President concerning the project.

Now to continue with the organization of the Council staff.

The general areas for which the program development staffs are responsible are: forecasting, technology assessment, pesticides, toxic substances, environmental education, occupational health, oceanographic programs, monitoring, population, natural resources, and research; water pollution, air pollution, noise pollution, and radiation standards; and secondary impact quantifications, costs of sprawl, solid waste, quantitative analysis, energy policy, economic impacts and costs of environmental controls, financing, computer applications, and operations research.

The Council's concern in the Great Lakes focuses on their importance as a critical national resource, as a center of commercial and industrial activity, and as an international boundary. While their pollution is representative of pollution in the United States, it is unique in that it cannot be successfully abated except by international cooperative action. Some of the Council's concerns in the Great Lakes are the construction and operation of municipal waste treatment facilities; the reduction of industrial, agricultural, and vessel pollutants; the presence of objectionable sludge and of harmful quantities of oil and hazardous polluting substances; the increases in the use of water, in population growth, in high-density urbanization and in resource development. The Council is concerned about recreational facilities, shoreline protection and the disposal of dredge spoil, about nutrient loading and eutrophication, the control of thermal effluents and about the grave deterioration of the Lakes' water quality. In sum, the Council's concern in the Great Lakes is not only in the prevention of further pollution, but also in their restoration and continued protection.

Let me not lead you into thinking that CEQ is concerned only with the Great Lakes, for those concerns which I mentioned are some of the kinds of things CEQ is concerned about in general. But let me assure you that CEQ does have concerns in the Great Lakes. I will conclude by mentioning some recent CEQ involvements in the Great Lakes Basin activities.

On an international scale they include the agreement with Canada to restore and protect the Great Lakes and the agreement with the Soviet Union which provides for joint projects on water pollution and the exchange of Lake Baikal data for data from Lake Tahoe and one of the Great Lakes. In this regard it is expected that Soviet specialists will be in the U.S. early next year.

On the national scene, CEQ is currently involved in the extension of the Great Lakes winter navigation season, in the issues surrounding the thermal discharges or proposed power plants, and, of course, in the continuing review of EIS covering proposed federal projects in the Basin.

A Review of the Role of the International Joint Commission in The Great Lakes

John F. Hendrickson, Executive Director,
United States Section, International Joint Commission

The International Joint Commission (IJC) has played a significant role in U.S./Canadian relations for over 60 years. Yet today it is an institutional entity about which relatively few people in either country know very much. This paradox is the result of the conservative public relations policies which have characterized the IJC over these many years, and the Commission's recent and sudden move into the environmental spotlight by reason of the significant responsibilities assigned to it under the terms of the Great Lakes Water Quality Agreement.

To understand what the International Joint Commission is and does, one must know something of the spirit and intent of the Boundary Waters Treaty of 1909 as well as the significant but unheralded achievements of the Commission down through the years.

The Boundary Waters Treaty was negotiated between the U.S. and Canada "... to prevent disputes regarding the use of boundary waters and to settle all questions which are now pending between the United States and Canada involving the rights, obligations and interests of either ... along their common frontier, and to make provisions for the adjustment and settlement of all such questions as may rise."

Some of the problems in dispute between the two countries at the turn of the century concerned the division of waters crossing the boundary at several points, and those waters which formed a part of the boundary, i.e., the Great Lakes, their connecting channels, Rainy River and the St. Lawrence and St. John Rivers.

The Boundary Waters Treaty recognized certain waters, such as the Great Lakes, as common waters with common rights to them held by both countries. It was obvious that an institutional arrangement would be necessary to assure both countries of those rights.

It is interesting to note that the early negotiations for the 1909 Treaty represented the first time that Canadians were the principal participants in such international negotiations acting for themselves. In all previous negotiations for international accords, Canadian interests were represented by the government of the United Kingdom. In addition, the Treaty which set up the International Joint Commission provided the Canadians an equal representation with the United States, a fact acclaimed by Canadians as they wrestle with their need to establish a national identity separate and apart from their rich and powerful neighbors.

The Commission came into being then in January of 1912 with three Commissioners to a side and small supporting staffs. Organizationally it hasn't changed a great deal in its 60 years. The three U.S. Commissioners are Presidential appointees who serve at his pleasure. The Canadian Commissioners are appointed by the Governor-General-in-Council and serve at the pleasure of the government.

Historically, the terms of appointment have run from one to ten years with only a few exceptions. Senator A. O. Stanley of Kentucky served 24 years (1930-1954) on the Commission (following his years of service on the Hill) 21 of which were as Chairman of the U.S. Section. The Honorable Charles A. Magrath served 25 years on the Canadian Section. Mr. Eugene W. Weber is now in his 25th year as a U.S. Commissioner.

The Treaty gives the Commission certain responsibilities in two general categories dealing with boundary waters. One, it approves or disapproves applications for use, obstruction or diversion of boundary waters on either side of the boundary which would affect the natural level or flow of the boundary waters on the other side. Examples include the control works in the St. Marys River at Sault Ste. Marie, the control works in the St. Lawrence River at the outlet from Lake Ontario, the power diversion structures on the Niagara River and others. Secondly, it is responsible for investigating and making recommendations for resolving specific problems referred to it by the two governments.

The Commission is in every sense an international agency. The matters with which it is concerned are referred to it by both governments by agreement. The Treaty provides that reference may be made by either government singly, but this has never occurred in the 60 years of the Commission's existence. The Commission acts as a single unit, half U.S. and half Canadian. Its actions are almost always unanimous (one exception in more or less 96 applications and problems it has considered). Its recommendations on solutions to problems are based on what will benefit both countries, but will not benefit one country at the expense of the other.

In other words, the Treaty enunciated certain rules and principles to be observed and to be uniformly applied by both countries and by the IJC in dealing with the waters flowing along or across the boundary. They were to ensure that both countries would share equally in access to and use of the boundary waters.

Even though our national consciousness has become critically attuned to air and water pollution problems afflicting the U.S. only within the last few years, the International Joint Commission began its consideration of these matters very early in its existence.

The Treaty conferred on the IJC no responsibilities with respect to water pollution, but provided in Article IV:

> It is further agreed that the waters herein defined as boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other.

As one can see, this provision was not self-executing, so it was necessary for the governments to take further action to deal with pollution matters. To do so, the governments turned to Article IX of the Treaty, which provides:

> The High Contracting Parties further agree that any other questions or matters of difference arising between them involving the rights, obligations or interests of either in relation to the other, along the common frontier between the United States and the Dominion of Canada, shall be referred from time to time to the International Joint Commission for examination and report, whenever either the government of the Dominion of Canada or the government of the United States shall request that such questions or matters of difference be so referred.

The second reference to the Commission, in August 1912, was a request from the governments to investigate the extent and causes of pollution in boundary waters, and to recommend means of remedying and preventing such pollution. The Commission submitted an interim report in 1914, and a final report in 1918. It found that transboundary pollution was occurring, principally in the Detroit, Niagara, St. Marys, St. Clair and St. Lawrence Rivers from vessels and municipal and industrial wastes, and that "conditions exist which imperil the health and welfare of the citizens of both countries in direct contravention of the Treaty."

In its 1918 report the Commission recommended construction of sewage treatment plants. It also recommended that the governments assign to the Commission regulatory authority over pollution in boundary waters and waters crossing the boundary.

As a consequence, the governments requested the Commission to prepare a draft treaty, or reciprocal legislation, which would implement this recommendation. The draft was written and submitted to governments on October 6, 1920.

The provisions of the draft treaty were modest, but many years ahead of their time. The Commission suggested that it be given authority to investigate any alleged violation of Article IV of the Boundary Waters Treaty and report on its findings. On the basis of these findings, which were to be "final and conclusive," the parties would take such actions as were necessary to prevent a continuation of the breach. The Commission was also to be given authority to define classes of vessels which would be required to install treatment devices to prevent pollution and the parties would agree not to license vessels which did not meet IJC specifications. Finally, there was to be agreement to enact or recommend to their respective legislatures for full enforcement of the convention.

The proposed treaty was never signed. The Commission has remained without regulatory or enforcement authority in the water pollution control field. Some students of international environmental law now suggest that had the Commission's foresight been rewarded, the Great Lakes would very likely not be in the heavily polluted condition that they are today.

So the problems of water quality became submerged in the public mind, due partially to the fact that chemical treatment of water supplies had been developed, thus offering a solution, though temporary, to one of the critical problems which had generated the reference, and probably also because the depression, recovery, and war years occupied the public concern.

After the war, however, it became apparent that the developing industrial complexes attracting a large labor force and resulting in rapid growth of cities were extracting a heavy price in the loss of water quality in the Great Lakes connecting channels—the Detroit, Niagara, St. Clair and St. Marys Rivers. The governments asked the Commission to investigate.

The Commission reported in 1950 with recommendations for remedial measures and water quality objectives for each country to seek to achieve. As a follow-up the governments asked the Commission to undertake a continuing surveillance program to determine what progress, if any, the parties were achieving in reaching the objectives.

During the next 15 years the Commission received references on the pollution problems in the Rainy River and Lake of the Woods between Minnesota and Ontario, the St. Croix River between Maine and New Brunswick, the Red River of the North which flows between Minnesota and North Dakota northward across the boundary into Manitoba, and on Lake Erie and Lake Ontario and the International Section of the St. Lawrence River.

In 1964 the governments requested the Commission to investigate and report on whether or not the waters of Lake Erie, Lake Ontario, and the International Section of the St. Lawrence River were being polluted on either side to the extent that was causing or was likely to cause injury to health or property on the other side. If so, to what extent, what were the causes, and in what localities? And, what remedial measures would it recommend, and the probable costs?

To conduct the study necessitated by this reference the IJC established two international investigative boards, one for Lake Erie and one for Lake Ontario and the St. Lawrence River.

The investigations were to last over the next six years. In 1965, the boards confirmed that serious water quality problems existed in the Lower Lakes. In 1968, the boards reiterated this fact in additional detail, and in 1970, they indicated that lake eutrophication, oil pollution and pollution from vessels needed prompt attention.

In December 1970, the final report of the Commission was submitted to Governments. It contained 22 recommendations, including common water quality objectives and continuing IJC surveillance. It recommended joint measures such as contingency plans for the cleanup of oil spills, improvements in municipal treatment facilities, control of nutrients (phosphates), coordination of research, etc.

Between June 1969 and June 1970, two Ministerial meetings were held and in June 1971, the governments announced they would enter into negotiations for an international agreement to implement many of the IJC recommendations.

A new momentum had been initiated. The Commission had called for new commitments for governments which the Commission itself could not command and could not implement.

A Great Lakes Water Quality Agreement was negotiated and signed in Ottawa on April 15, 1972, by President Nixon and Prime Minister Trudeau.

The Great Lakes Water Quality Agreement may be perhaps the most comprehensive and far-reaching agreement ever concluded between two nations on an environmental problem of mutual concern.

The role of the IJC under the new agreement, while similar to the function it now serves, will be substantially larger. Governments have relied on Article IX of the 1909 Treaty to give the IJC surveillance responsibilities for the entire Great Lakes System. It will report to governments at least annually on the progress being achieved under the Agreement.

No enforcement role has been designed for the Commission, but authority for public disclosure represents a significant new force to add to the Commission's influence which it has developed over the years. The Agreement specifically empowers the Commission to make public any of its reports or findings without the prior approval of either government.

The Commission will assist in the coordination of programs in both countries to implement the Agreement, and it will monitor and evaluate the effectiveness of programs on both sides of the boundary.

The activities of any agency of government at any level which are concerned with the quality of boundary waters are of interest to the Commission. The Commission's role seems to be one of superimposing the latter on the former, encouraging and coordinating actions on both sides of the boundary with only a handful of men and hardly a pocketful of money.

The Commission has begun its efforts.

- It has appointed a Great Lakes Water Quality Board to advise the Commission on all matters relating to the Water Quality Agreement.
- It has appointed a Research Advisory Board to advise and assist the Commission in coordinating water quality research in both countries.
- It has appointed a study team to report on pollution problems in Lakes Huron and Superior.
- It has appointed a study team to look into the effect of land use activities on water quality in all the Great Lakes.
- It has appointed a study team to look into and report on dredging practices and laws on both sides of the border and recommend compatible regulations.
- It is in the process of establishing a regional office in Windsor, Ontario, to assist the various boards and the Commission to meet their responsibilities under the Agreement.

If the concepts which have been developed by the Great Lakes Water Quality Agreement from the 60 years of the IJC experience are valid, it is highly possible that we will see an extension of such arrangements all along the border and on a broad range of problem areas which are likely to exist always between the U.S. and Canada.

Role of the Great Lakes Fishery Commission

Robert Saalfeld, Director, Great Lakes Fishery Commission

The need for international cooperation in the conservation of fishery resources in the Great Lakes was officially recognized as early as 1897. Since that time, several temporary boards and commissions were established by the United States and Canada to advise governments on measures to conserve the fisheries. However, the measures proposed were mainly restrictive and failed to obtain the unanimous support required for implementation.

In 1940 the United States and Canada established an international board of inquiry for the Great Lakes fisheries which, after surveying conditions, recommended that the fishery should be investigated by a common or joint agency which would be responsible for formulating and testing measures to improve production. Attempts to establish such a body were delayed by World War II. In 1946 a Convention was drafted but never ratified because of vigorous opposition to a provision which granted authority to a commission to regulate the fisheries. However, intensifying problems of conservation, particularly the severe depredations of the parasitic sea lamprey, led to a review and modification of early treaty drafts and finally to the ratification of the present Convention in 1955.

The Convention provided for the establishment of the Great Lakes Fishery Commission, which was assigned the duties of: (1) formulating and coordinating fishery research programs, (2) advising governments on measurements to improve the fisheries, and (3) implementing a program to control the sea lamprey.

The Commission was also asked to make use of existing agencies in carrying out its duties wherever possible, and fortunately we have been able to do so, mainly through the cooperation of federal, state, and provincial agencies.

Commission Organization

The Commission has eight members, four from Canada and four from the United States. A small headquarters staff is maintained in Ann Arbor, Michigan. The United States Section is served by an advisory committee for each Lake on which bordering states may be represented by not more than four persons. In making appointments, the United States Section selects from persons recommended by the respective governors, giving due consideration to representation of the following interests:

(1) state agencies having jurisdiction over fisheries

(2) commercial fishing industry of the Lake
(3) sport fishing industry of the Lake and
(4) public-at-large.

It should be obvious that the Great Lakes Fishery Commission is largely an advisory and coordinating body with direct control over only one segment of Great Lakes operations, sea lamprey control. Arrangements for carrying out the latter responsibility are relatively straightforward. The Commission develops the program and each year requests funds from the two governments (69 percent from the United States and 31 percent from Canada). When allocations are made, the Commission contracts with the U.S. Bureau of Sport Fisheries and Wildlife to carry out operations in the United States, and the Canadian Department of the Environment to carry out operations in Canada.

The development and coordination of research and the appropriation of funds to undertake such research are much more difficult tasks. In order to develop cooperation in the planning and execution of research programs and management measures, the Commission has established technical committees for each of the Great Lakes (these are not to be confused with advisory committees to assist the United States Section in policy matters). The technical Lake committees are made up of senior officials from agencies in the United States and Canada administering the fishery with advisors from agencies and/or institutions engaged in research. The committees review annually the status of fish stocks, coordinate research and management, and make recommendations to the Commission on matters of international concern. The Commission will frequently ask a committee to provide certain information or to consider problems which the Commission believes are critical.

The Commission also has four central committees to consider the Great Lakes fishery and its problems as a whole and to oversee its own headquarters operations. These are the Scientific Advisory Committee, Sea Lamprey Control and Research Committee, Management and Research Committee, and Finance and Administration Committee.

The Commission conducts its official business, including the submission of recommendations and requests for funds, through the Department of State of the United States and the Department of External Affairs of Canada. These Departments, if they approve the recommendations, refer them to the appropriate federal, state, or provincial agency.

The complex committee organization for carrying out the Commission's responsibilities is largely the result of the divided jurisdiction of the Great Lakes fishery. In a very real sense the Commission is not dealing simply with two countries but with eight states and the province of Ontario as well, and their sociological and economic interests are not always the same. Their involvement at every stage in planning is, therefore, essential and the committees serve this purpose. In these circumstances the Commission focuses its attention on developing fish stocks for a variety of uses. In some areas the sport fishery is the primary consideration while in others it is the commercial fishery. In many areas a judicious mixture of both uses of the resource will undoubtedly bring the greatest sociologic and economic benefit. The Commission can say little regarding the use made of a fish stock provided its productivity is not jeopardized, but it is concerned in seeing that the fishery resource provides the best return possible to the two countries' investment in lamprey control.

Since the entry of sea lamprey into the Upper Great Lakes in the 1920's and the tremendous population explosion by the alewives in the 1960's, the most noticeable feature of the Great Lakes fisheries is their instability and rapid change. During the last 30 years, lake trout were virtually eliminated by the sea lamprey except in Lake Superior, where remnant populations remained. Stocks of whitefish were also severely damaged. Several species of large deep-water ciscoes have become virtually extinct. Lake herring and whitefish have almost vanished from Lake Erie, and herring populations in Lakes Michigan and Huron no longer contribute significantly to the commercial catch. The lake herring population in Lake Superior has declined severely. The situation with chubs is comparable. The blue pike in Lake Erie has, for all practical purposes, disappeared. Walleye populations in Lakes Michigan and Huron have declined to only an incidental part of the commercial fishery.

Despite the obvious deterioration of the resource over the past two or three decades, much cause for optimism remains. The lamprey control program has demonstrated its worth. Restoration efforts with the lake trout, Pacific salmon, and other salmonids have been outstandingly successful to date. The establishment and expansion of the most dramatic sport fishery in the history of the Great Lakes is of tremendous importance. Environmental deterioration is not yet severe enough to preclude the recovery of stocks. The resiliency of the resource, as shown by the frequent appearance of strong year classes of most species in various parts of the Basin, suggests that with wise management the present fishery resource can be enhanced and maintained for future users.

Long-term environmental deterioration in the Great Lakes has included biological factors such as disruptions brought about by the sea lamprey, alewives, and an intense and selective fishery. Physical deterioration has been accelerated by domestic, agricultural, and industrial pollution, all of which have contributed to lowered water quality, especially in inshore areas. In addition, contaminants such as pesticides and heavy metals have and will continue to have deleterious effects on the fishery resource. A few examples will suffice. Over the past few years, the state of Michigan has been forced to destroy several million pounds of potentially harvestable coho and chinook salmon owing to DDT and PCB contamination. Commercial fishing for walleye and white bass in Lake Erie has been closed because of mercury contamination. Similar closures have been imposed on the commercial chub fishery in Lake Michigan owing to excessive DDT residues. Each new problem creates a new crisis and further erodes public confidence in the safety of the fishery product.

Continuing degradation of water quality will continue to jeopardize the present and potentially greater benefits from the fish resources of the Great Lakes. Corrective measures are painfully slow and could stop short of providing adequate protection for fish albeit satisfactory from the standpoint of human health. We feel, however, that there is an alternative to the present approach which should involve a change in the way issues are handled. Human health is certainly a major concern. However, it seems incredible that we must wait to react to an environmental problem until it becomes important to human health. Then all our energies and all our concern center on protecting the public from eating fish rather than insuring better protection for our environment. We feel strongly that water quality standards should be related to sensitive concentrating organisms like fish, so that controls can be initiated at the "factory fence" before natural resource products are condemned.

The Role of the International Association for Great Lakes Research in Research of the Great Lakes

John F. Carr, Treasurer, International Association for Great Lakes Research

ABSTRACT

The first conference on Great Lakes Research, held in July 1953, represented the first meeting of Great Lakes investigators for the discussion of common problems and needs and the exchange of ideas about the present status of research on these Lakes and future plans. By the time of the Fourth Conference in 1961, it was apparent that the conference should be held annually.

At the Ninth Conference in 1966, it was decided that a formal organization was needed to sponsor the conferences on Great Lakes research. Bylaws were adopted, and the first formal meeting of the International Association for Great Lakes Research (IAGLR) was held in 1967 at the time of the Tenth Conference. The objectives of IAGLR were stated as "the promotion of all aspects of Great Lakes research and the dissemination of research information through publications and meetings."

The conferences have contributed importantly to the promotion and conduct of research on the Great Lakes, serving as an effective means of communication through discussion and publication, and as a common meeting ground for those concerned with Great Lakes problems.

The International Association for Great Lakes Research will continue to sponsor the annual conferences, but in addition the membership has been broadened to include all persons interested in research and problems of the great lakes of the world. Membership now includes engineers, economists, sociologists, political scientists, legal experts, and regional planners, as well as those in the natural sciences.

A seven-member Board of Directors manages the affairs of the Association and is responsible for long-term planning and continuity of its programs and activities. Membership in the Association is open to persons who are actively interested in research on the Great Lakes and their basins, or in research directly applicable to the understanding of management of large lakes.

The Sixteenth Conference on Great Lakes Research will be held in Sandusky, Ohio, April 16-18, 1973; the Center for Lake Erie Area Research (CLEAR) of Ohio State University will be the host. Great Lakes area universities have been hosts for most of the conferences; however, federal agencies have been cohosts of two recent conferences—the Great Lakes Fishery

Laboratory in 1969 (with the University of Michigan) and Canada Centre for Inland Waters in 1971 (with the University of Toronto).

* * *

INTRODUCTION

The International Association for Great Lakes Research (IAGLR) is a unique professional society composed of a heterogeneous group of men and women with a strong interest in and concern for the Laurentian Great Lakes. Its uniqueness stems from the members' common tie to the Lakes themselves, not to a specific field of interest or an organization. Many of the founders represented only an individual's personal interest in a Great Lakes phenomenon, but some also represented small governmental or university units that have now become large Great Lakes research organizations, some with annual budgets exceeding $1 million.

HISTORY OF GREAT LAKES RESEARCH CONFERENCES

The Association had its origin in July 1953 (14 years before it became a professional membership society), when the First Conference on Great Lakes Research was held at the University of Michigan Biological Station at Douglas Lake. The conference was sponsored by the Great Lakes Research Institute (now the Great Lakes Research Division) of the University of Michigan and attended by about 50 persons representing the areas of hydrology, meteorology, geology, limnology, and fisheries. From the beginning the conference was multi-disciplinary and international; at the first meeting a cooperative research program on Lake Huron was agreed upon for the summer of 1954 by the Ontario Department of Lands and Forests and the Great Lakes Research Institute of the University of Michigan. Thus, 1954 could be considered as the first International Field Year for the Great Lakes.

The First Conference, the Second Conference (which was held at the University of Michigan in 1955), and to some extent the Third Conference (which was also held at the University of Michigan, in 1959) consisted primarily of discussions of the "Present Status and Future Needs of Research" on the Great Lakes, presented primarily as agency reports. For the first time, however, the Proceedings of the Third Conference contained a few strictly technical papers, in addition to 21 agency progress reports.

The first three conferences resulted in the formation of a nucleus of Great Lakes managers who were informed of each other's research responsibilities and goals. These meetings also brought up to date the status of knowledge on the Great Lakes and, equally important, exposed the wide gaps in that knowledge. Coordination of research was not specifically attempted in these or later meetings; it was felt that open communication between those responsible for Great Lakes research would produce its own coordination.

From 1961 (when the Fourth Conference on Great Lakes Research was held) to the present, the format of the Conferences has been the same—the presentation of technical papers and special speakers or symposia on current topics of interest. Also, beginning with the Fourth Conference, the meetings have been held annually.

No history of IAGLR would be complete without special mention of the role of one man who, more than any other, was responsible for the Great Lakes Research Conference and the creation of IAGLR. That man is Dr. David Chandler, Director of the Great Lakes Research Division of the University of Michigan. He and the Great Lakes Research Division served as the host to the first four conferences, as well as the Sixth, Eighth, and Twelfth. His division also edited, published, and financed all Conference Proceedings from the First through the Tenth. If it had not been for Dave Chandler, IAGLR probably would not now exist.

CREATION OF IAGLR

In 1965, after years of providing the initiative and responsibility for the Great Lakes Research Conference, the Great Lakes Research Division indicated that it would welcome assistance with these responsibilities from other Great Lakes organizations. In March 1965 a Steering Committee of five men (including three federal representatives) was formed to assist in guiding conference activities. In a series of developments in 1966, the Steering Committee decided in January that a formal organization should be established to conduct the Conferences and publish the Proceedings; presented plans for a formal organization of the Ninth Conference in March, and was authorized by the conferees to proceed; and adopted a set of Bylaws for an International Association for Great Lakes Research in September. The Bylaws and invitations to join were circulated to those who had attended previous conferences. At the time of the Tenth Conference, in 1967 (the first held under the auspices of IAGLR), there were 225 members.

Purpose and Objectives of IAGLR

The creation of an Association did not change the basic purpose of the annual Great Lakes Research Conference nor the publication of the Proceedings. It has, however, provided a more formal bond for those directly involved in Great Lakes research and also to those professionally and personally interested in the Great Lakes. As stated in the Bylaws, the objectives of the Association are "the promotion of all aspects of Great Lakes research and the dissemination of research information. . ." The only criterion for membership is an active interest in research on the Great Lakes and their basins or in research directly applicable to the understanding or management of large lakes. The Association has on several occasions declined to include the presentation and publishing of papers on other freshwater systems (small lakes, rivers, reservoirs) and each time has reaffirmed the organization's orientation to the Great Lakes.

Management of IAGLR

The affairs of IAGLR are managed by a seven-man Board of Directors and a Secretary and a Treasurer, all elected for three-year terms by the membership. The Board must include at least two members from Canada and at least two from the United States. Traditionally, the Presidency has alternated between Canada and the United States. There is no compensation to any elected or appointed official of the Association. Only the direct expenses of preparing and publishing the Proceedings are paid by the Association.

GREAT LAKES RESEARCH CONFERENCES

Attendance at the annual Great Lakes Conference grew from 50 at the First Conference to more than 600 at the Fifteenth, in 1972. The conference usually lasts three days and provides a program of over 100 technical papers and several "specialty" symposia. All papers have a direct bearing on some aspect of the Laurentian Great Lakes. Regular attendance at these conferences provides the serious Great Lakes researcher with an opportunity not only to be informed of the research being conducted in his area of interest, but also to have personal contact with his fellow researchers. The range of subjects covered by the technical papers is as diverse as the fields of interest represented by the membership.

Although IAGLR sponsors all Great Lakes Research Conferences, the host institution is responsible for arranging the sessions and selecting the papers to be presented. In addition, the host is free to invite speakers of his choice and to organize symposia. Traditionally, the host institution has been a Great Lakes area University; however, the cohosts of two recent conferences have been Federal agencies—the Great Lakes Fishery Laboratory in 1969 (with the University of Michigan) and the Canada Centre for Inland Waters in 1971 (with the University of Toronto). The Center for Lake Erie Area Research (CLEAR) of Ohio State University will be the host of the Sixteenth Conference on Great Lakes Research, to be held in Sandusky, Ohio, April 16-18, 1973.

PUBLICATIONS OF IAGLR

The only formal publication of IAGLR is the annual Proceedings of the Great Lakes Research Conference. Only papers given at the Conference have been published in the Proceedings. Not all papers presented are submitted for publication, and those that are submitted must undergo critical editorial review. About 50 to 60 percent of the papers presented are published in the Proceedings. Each of the Proceedings for the past several years has contained more than 50 papers on Great Lakes research.

Beginning in 1973 the Proceedings will also include notes on Great Lakes subjects; these papers are not required to be given at the annual conference.

The Association also publishes a quarterly "Lakes Letter" for the membership. This newsletter includes informal items on Great Lakes organizations and people, and a guest editorial on a timely Great Lakes issue.

COMPOSITION OF THE MEMBERSHIP

There are about 525 members in IAGLR (70% United States, 29% Canada, 1% foreign). The membership represents a number of types of agencies (Table 1) and a variety of principal fields of interest (Table 2). A total of 48 (14%) of the United States members and 48 (35%) of the Canadian members are employees of the respective federal governments. Perhaps this difference in percentage of direct federal participation (14% versus 35%) reflects the manner in which each federal government has chosen to conduct research in the Great Lakes–Canada primarily by direct involvement and the United States primarily by contracts and grants to universities.

Thirty United States members (9%) are employed by state agencies and 21 Canadian members (15%) by provincial organizations. The fastest growing group of members is affiliated with private (not tax supported) firms–55 members (16%) from the United States and 15 (11%) from Canada. Many of these members work for environmental consulting organizations.

Table 1: Membership in IAGLR, by type of employment, 1972
(Canadian and United States members only)

	Number of members	
Type of employment	United States	Canada
Interstate	4	–
Federal	48	48
State or Provincial	30	21
Municipal	0	2
University	209	50
Private	55	15
Unknown	3	1
Total	349	137

Table 2: Membership in IAGLR by field of interest, 1972
(Canadian and United States members only)

	Number of members	
Discipline	United States	Canada
Biologist	154	45
Chemist	35	10
Engineer	47	20
Geologist	33	18
Mathematician	4	–
Meteorologist	22	11
Physical limnologist	37	20
Resource planner	17	13
Total	349	137

The university contingent of the membership differs significantly between the U.S. and Canada, which apparently reflects the difference in university funding by the two federal governments. In the United States 209 members (60% of the membership) are affiliated with 58 colleges or universities; in Canada the number is only 50 (37%).

Biologists are the most numerous group of IAGLR members in both the United States (154 members; 44%) and Canada (45 members; 33%). Of the U.S. members, 13% are engineers, 11% physical limnologists, 10% chemists, 9% geologists, 6% meteorologists, 5% resources planners, and 1% mathematicians. The percentages are similar among the Canadian members, although slightly higher for most disciplines because of the lower percentage of biologists.

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